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ORIGINAL ARTICLES.

Some Early Mesozoic Plants from the Tanganyika Territory.

By A. C. SEWARD, Sc.D., F.R.S.

(PLATES XIX AND XX.)

THE specimens described in the following pages were submitted to me for examination by Mr. F. R. Parrington, who obtained them " from the hard fine-grained flags in the bed of the Msimbasi River between the junction of a tributary called the Katkindu and the site where reptile remains (? *Tangasaurus menneli*) were collected about half a mile above the junction, approximately 4° 55′ S. lat.; 38° 57′ long." (Sketch-map, I.) Though the material is for the most part fragmentary, it is a welcome addition to the palaeobotanical records from tropical Africa. The plants are from the region where Dr. E. O. Teale[1] made a collection, which was described twelve years ago. Specimens from the same district and from beds of the same geological age had previously been described by Potonié.[2] Teale assigned the plant-beds to the middle division of the Tanga series of the Karroo system and Potonié regarded the beds at his " Fundort V ", which corresponds to Mr. Parrington's locality (sketch-map, I) as Rhaetic-Jura (?). My conclusion was that the plants indicated a Triassic or Rhaetic age. The additional fossils which Mr. Parrington kindly handed to me, though they cannot be said definitely to settle the age of the beds, indicate an Upper Triassic horizon.

DESCRIPTION OF THE FOSSILS.

GINKGOALES. *Baiera tanganyikensis* sp. nov., Pl. XIX, Fig. 1.

The specimen, reproduced approximately half natural size, is probably part of a broader leaf deeply dissected into several groups

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[1] Seward, A. C., " On a small collection of Fossil Plants from the Tanganyika Territory," GEOL. MAG., LIX, 1922, 385.

[2] Potonié, H., " Fossile Pflanzen aus Deutsch- und Portugiesisch-Ostafrika," *Deutsch-Ostafrika*, 1900, 7.

of divergent segments. The portion preserved is 22 cm. long; the linear segments are 2–3 mm. broad and converge to a common base 3–5 mm. broad. There are traces of parallel veins.

Similar though shorter pieces of *Baiera* leaves were found by Dr. Hamshaw Thomas,[1] but not yet described, in the Molteno beds of Natal. Others were described by Feistmantel[2] as *B. schencki* from plant-beds on the Indwe River in Cape Colony, assigned by him to the Stormberg Series. There is a fairly close agreement with leaves figured by Fontaine[3] as *B. multifida* Font. from Upper Triassic beds in Virginia. In his description Fontaine states that the complete leaf must have been at least 25 cm. long. Comparison may also be made with *B. simmondsi* (Shirley)[4] from the Ipswich Series of Queensland.

CONIFERALES. *Cupressinocladus harrisi* sp. nov., Pl. XIX, Fig. 2; Pl. XX, Fig. 8.

The specimens shown in Figs. 2 and 8, approximately twice natural size, do not afford conclusive evidence of their morphological nature or systematic position; they are probably branches of a woody plant bearing decussate leaves. The specimen reproduced, twice natural size, in Fig. 8, bears a superficial resemblance to the Equisetaceous genus *Phyllotheca*, but examination of the excellent photographs taken for me by Dr. Harris furnished indications of appendages closely appressed to the axis midway between the pairs of linear appendages clearly shown at two of the nodes. Similarly on the specimen shown in Fig. 2 there are dark patches on the axis between the paired appendages. In order, if possible, to obtain more definite evidence, Dr. Harris kindly made a transfer preparation of the fossil shown in Fig. 2, and this revealed the presence of a linear appendage detached from the rock and lying parallel to and over the axis. The appendages are fairly stout; there are two at each node; they are certainly not thin segments of sheathing leaves such as those of a *Phyllotheca*. The decussate leaves are decurrent and suggest comparison with those of some species of *Juniperus* and the Australian conifer *Callitris*. The strobilus seen in Fig. 2 consists of several flattened scales, broadly triangular and with acute apices.

Rather than propose a new generic name I have assigned these fossils to *Cupressinocladus*,[5] believing them to be branches of a conifer of a type not, so far as I know, previously recorded. They are named after Dr. T. M. Harris.

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[1] I am indebted to my colleague, Dr. Thomas, for drawing my attention to these and other fossils in his collection, which agree more or less closely with some of Mr. Parrington's specimens.

[2] Feistmantel, O., "Die Karoo-Formation und die dieselbe unterlagernden Schichten," *Abh. k. böhm. Ges. Wiss.*, vii. Folge, iii, 1889.

[3] Fontaine, W. M., "Contributions to the knowledge of the older Mesozoic Flora of Virginia," pts. 45–7, *U.S. Geol. Surv.; Mon. vi*, 1883.

[4] Walkom, A. B., "The Flora of the Ipswich and Walloon Series," pt. 2, *Queensland Geol. Surv. Publn.*, No. 259, 1917.

[5] Seward, A. C., *Fossil Plants*, vol. iv, p. 303, 1919.

Voltziopsis Potonié.

i. Foliage shoots, Pl. XIX, Fig. 5; Pl. XX, Figs. 9, 10.
ii. Cone-scale, Pl. XIX, Fig. 4.

The collection includes several fragments of foliage-shoots, with spiral leaves, borne by one or more species of conifers, associated with detached, lobed cone-scales. In vegetative features the specimens conform to *Brachyphyllum* (Fig. 9) and *Pagiophyllum* (Fig. 5), *Voltziopsis*, *Voltzia* (Fig. 10), *Cheirolepis*, etc. Some of the branches are undoubtedly specifically identical with Tanganyika fossils named by Potonié [1] *Voltziopsis*, a genus reduced by Gothan [2] to sub-generic rank and compared with Heer's *Leptostrobus*. The cone-scales are also of the same type as Potonié's, and it is their presence which leads me to adopt the name *Voltziopsis* as a provisional designation pending the discovery of material affording more definite evidence of affinity.

In some of the fragments (Fig. 9) the leaves are closely appressed to the branch as in *Brachyphyllum*; in others (Fig. 5) the free portion of the leaf is more prominent, and in one or two fragments, which are not reproduced, the leaves are longer and suggest comparison with the foliage-shoots of *Araucaria excelsa* and other species, as in the imperfectly preserved example previously figured as *Ullmannia*.[3] The piece represented in Fig. 10 differs in the much greater length of the stiff leaves, which reach a length of 3 cm.; the base of the thick lamina is decurrent. This specimen resembles *Voltzia liebeana* Gein. from the Zechstein of Germany [4] and one figured by du Toit [5] from the Molteno beds of South Africa as *Voltzia* cf. *liebeana*.

It is impossible to assign these specimens to a precise position, or to say whether or not they are specifically distinct one from another; or whether, as seems possible, some of them at least are pieces of one heterophyllous conifer. A few of the fragments resemble branches of *Cheirolepis* recently figured by Hörhammer [6] from the Rhaetic-Lias of Germany, but without the evidence of cuticular preparations or seed-scales little weight can be given to external characters of vegetative shoots.

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[1] Potonié, loc. cit.

[2] Gothan, W. In Potonié's *Lehrbuch der Paläobotanik* (edit. 2), 322. Berlin, 1921.

[3] Seward (1922), pl. xvii, fig. 7.

[4] Geinitz, H. B., "Nachträge zur Dyas I," *Mitt. k. Mineralog. Geol. und Praehist. Mus., Dresden*, iii, pl. v.

[5] du Toit, A. L. "The Fossil Flora of the Upper Karroo Beds," pl. xxi, fig. 3, *Ann. S. African Mus.* xxii, pt. 2, 1927.

[6] Hörhammer, L., "Über die Coniferen-Gattungen *Cheirolepis* Schimper und *Hirmeriella* nov. gen. aus dem Rhät Lias von Franken," *Bibliotheca Botanica*, Heft 107, 1933.

CONE-SCALES. *Voltziopsis africana* sp. nov. Pl. XIX, Fig. 4.

There are several short and broad scales with five, six, or more broadly oval lobes which are no doubt specifically identical with Potonié's *Voltziopsis* scales [1] and with those previously figured by myself [2] as *Voltzia* from the same district. The specimens hitherto obtained do not furnish evidence of structure nor of the position and number of the seeds; they are very similar to cone-scales of *Voltzia* and may be compared also with scales of *Cheirolepis*.[3] The scale shown in Fig. 4 is 9 mm. broad and had, probably, at least six short and relatively broad lobes on the upper margin; the stalk is short and broad and there are indications of a central vascular strand, and other strands passing obliquely upwards towards the lobes.

FOLIA INCERTAE SEDIS. *Desmiophyllum* Lesquereux.

Mr. Parrington found several incomplete linear leaves unconnected with stems which cannot be referred to a systematic position; no preparation of cuticle-films could be obtained. As frequently happens in describing material of uncertain affinity a difficult question of nomenclature is raised. On the whole my preference is for the non-committal name *Desmiophyllum*, which has often been used for leaves superficially resembling those of *Cordaites* or *Phoenicopsis*. Alternatively, the name *Pelourdea* [4] might be employed, but it is preferable to reserve it for leaves which have been described under the misleading designation *Yuccites*.

Desmiophyllum parringtoni sp. nov. Pl. XIX, Fig. 3.

The largest leaf (Fig. 3), incomplete at both ends, is 8 cm. long and has a maximum breadth of 1·8 cm. A distinctive feature is the wide spacing of the veins, which are approximately 2 mm. apart; the lamina has an entire margin and is slightly narrowed towards one end. The photograph, for which I am indebted to Dr. Harris, shows the venation more clearly than in the actual specimen.

Desmiophyllum spp. Pl. XX, Figs. 6, 7.

Fig. 6.—The longer and narrower leaf is 8·3 cm. long and has a maximum breadth of 6 mm.; the apex is obtuse and the coarsely ribbed lamina tapers to the incomplete basal end. This leaf is probably specifically identical with that in Fig. 7. The smaller specimen, 5 cm. by 8 mm., has more numerous and finer veins.

Fig. 7.—This curved leaf, approximately 9 cm. long, has an obtuse apex; the lamina tapers gradually towards the base. It is

partially covered with a film of coal on which there are numerous vein-like lines; the surface below the coaly layer is more coarsely ribbed.

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[1] Potonié, loc. cit., p. 10.

[2] Seward (1922), pl. xvii, figs. 8 and 9.

[3] Hirmer and Hörhammer "Zur weiteren Kenntnis von *Cheirolepis* und *Hirmeriella*, etc.," *Palaeontographica*, Bd. lxxix, Abt. B, 1934.

[4] Seward, A. C., *Fossil Plants*, iii, 1917, 278.

The leaf shown in Fig. 7 and the larger of the two in Fig. 6 are almost certainly specifically identical with the Tanganyika leaf previously described as ? *Eretmophyllum* sp. In discussing possible affinities I wrote: "It is difficult to assign this species, i.e. the specimen shown in fig. 1, Pl. 17, of my earlier paper to a precise systematic position; while superficially resembling some leaves of *Schizoneura* figured by Feistmantel from Gondwana beds in India, the agreement is by no means sufficiently close to justify inclusion in that genus. It resembles also detached leaves figured by the same author from Jurassic (Upper Gondwana) rocks in India, and referred on insufficient evidence to the Jurassic European species *Podozamites lanceolatus*. The Tanga specimen is, I am convinced, not a leaf of *Podozamites*. It may, however, be closely allied to some leaves of similar form described by Dr. Hamshaw Thomas[1] from Jurassic rocks of Yorkshire and assigned by him to a new genus, *Eretmophyllum*." An examination of the recently discovered material strengthens my opinion that the leaves are neither *Schizoneura* nor *Podozamites*, and almost certainly not *Eretmophyllum*. This and some of the other leaves may also be compared superficially with impressions from Jurassic rocks in northern Caucasia figured by Kryshtofovitch[2] as species of *Macrotorellia*. There are many fossil leaves from Palaeozoic and Mesozoic rocks which resemble more or less closely the African specimens; e.g. Triassic leaves assigned to *Yuccites*[3] and a Rhaetic species, *Phyllotenia* (?) *hadroclada*, described by Halle[4] from Scania. The closest resemblance is with leaves, not yet described, obtained by Dr. Hamshaw Thomas from Molteno beds in Natal and Cape Colony; his collection includes many linear leaves varying considerably in size, and none attached to a stem. One of the Cape Colony specimens is an incomplete leaf, 11 mm. broad, in which the veins are approximately 1 mm. apart, as in the Tanga fossil shown in Fig. 3. It would seem highly probable that the Molteno leaves are generically identical with those from the Tanga beds, but pending information on the cuticles or other additional evidence of affinity their systematic position cannot be determined.

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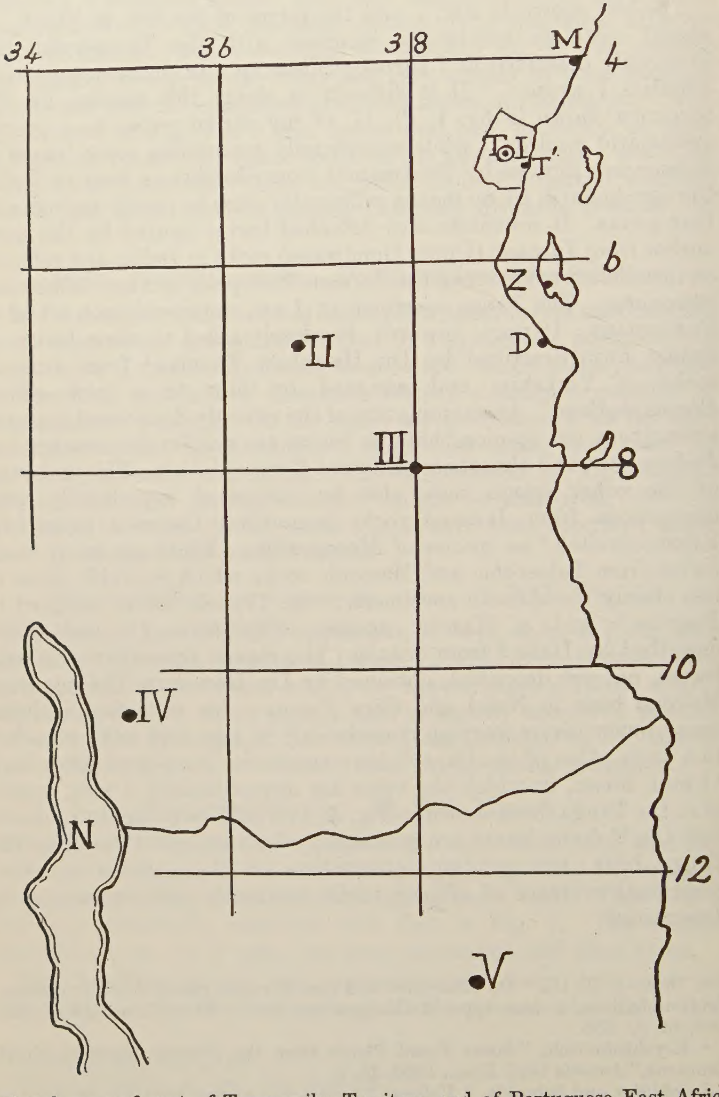
[1] Thomas, H. H., "On some new and rare Jurassic plants from Yorkshire: Eretmophyllum, a new type of Ginkgoalean leaf," *Proc. Camb. Phil. Soc.*, xvii, pt. 3, 256.

[2] Kryshtofovitch, "Some Fossil Plants from the Jurassic State of North Caucasus," *Izvestia Geol. Kom.*, 1926, 45, v.

[3] Schlüter and Schmidt, "*Voltzia, Yuccites* und andere neue Funde aus dem südhannoverschen Buntsandstein," *Neues Jahrb. Min. Beilageband*, 57, Abt. B, 1927.

[4] Halle, T. G., "A Gymnosperm, with Cordaitean-like leaves from the Rhaetic beds of Scania," *Arkiv. Bot.*, Bd. 9, 1910.

Mr. Parrington's collection includes several pieces of flattened, partially carbonized stems or rhizomes, which are indeterminable.



Sketch-map of part of Tanganyika Territory and of Portuguese East Africa. T = the Tanga province ; T′ = Tanga ; M = Mombasa ; Z = Zanzibar ; D = Dar-es-Salaam ; N = Lake Nyassa ; I = the locality where Mr. Parrington's fossils were collected. II–V, other localities mentioned in the text.

GEOLOGICAL AGE OF THE TANGA PLANT-BEDS.

After describing Dr. Teale's specimens I wrote: "Taking into account the whole of the palaeobotanical evidence, my opinion is that while some of the specimens agree more closely with European Zechstein forms than with any later species, the balance of evidence points to a higher horizon, whether Triassic or Rhaetic cannot be definitely determined. If it is assumed that the absence of *Glossopteris* means its non-existence in the Tanga flora, this would furnish an argument in favour of a geological position at least as high as uppermost Triassic or Rhaetic."[1] An important consideration, in this as in many other similar instances, is the value to be attached to negative evidence. *Glossopteris* has been recorded from several localities in the Tanganyika Territory; also from Portuguese East Africa (sketch-map, V). The most recent record of its occurrence in Tanganyika is by Mr. L. S. Robertson,[2] who described two species obtained by Mr. G. M. Stockley from rocks on the Upper Gombati River, which he correlates with the Ecca Series (sketch map, II). *Glossopteris* has also been found at locality III on the map, and *Vertebraria* at locality IV.[3] *Glossopteris* has not been found in any place associated with plant-remains such as those recently discovered by Mr. Parrington. The upper geological limit of the genus is a little uncertain; Dr. du Toit states that it occurs "right up in Zone D" in the Molteno beds. If du Toit's identification is correct the Molteno beds, as he says, "provide the only instance yet known of the survival of *Glossopteris browniana* into Trias-Rhaetic times."[4]

Dr. S. H. Haughton,[5] in his paper on Reptilian remains from beds near Tanga, wrote: "Mr. Mennell informs me that he obtained *Glossopteris* from a horizon just above that which yielded the remains described in this paper." In an account of the Karroo System communicated to the International Geological Congress in 1929 Mennell referred to the occurrence of *Glossopteris* just above the reptilian horizon and added: "The absence of *Glossopteris*, however, on which much turns, does not appear to be a fact, and that fossil has been recorded from a bore hole penetrating the Taru grits in Kenya."[6]

Dr. Teale, who also refers to Mennell's statement that *Glossopteris* was found in the Tanga region, says that there are at least eight definite and separate occurrences of Karroo rocks in the Territory, and reminds us that "the greater part of the country still requires examination before anything like a complete map can be produced".[1]

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[1] Seward, loc. cit. (1922), p. 391.

[2] Robertson, L. S., "Report on some Fossil Plants collected in Tanganyika Territory," *Quart. Journ. Geol. Soc.*, xc, 1934, 1.

[3] Potonié, loc. cit.; localities III and IV are his localities IV and II.

[4] Toit, A. L. du, loc. cit., p. 367.

[5] Haughton, S. H., "Reptilian remains from the Karroo beds of E. Africa," *Quart. Journ. Geol. Soc.*, lxxx, 1924, 1.

[6] Mennell, F. P., "The Karroo System in East and Central Africa," *Int. Geol. Congress*, 1929, 263.

We have as yet no proof of the occurrence of *Glossopteris* in the Tanga beds in the region (sketch-map, I) from which Potonié, Teale, and Parrington collected fossils. It is, therefore, of great importance that Mr. Mennell should describe his specimen and state the relation of its provenance to that of the other Tanga plants. Mr. Parrington tells me that he made a special point of searching for *Glossopteris*; he failed to find it. We might account for the failure by assuming that the Tanga plants are only a very incomplete sample of the contemporary vegetation, scraps carried by water from one type of habitat. *Glossopteris* may have been living in a place remote from the source of supply of the sediment of which the plant-beds are made. This is a possibility. It is perhaps more probable that *Glossopteris* was not a member of the Tanga Flora and was no longer a living genus.

The plants described in this contribution afford additional evidence in favour of an Upper Triassic age of the Tanga beds; the discovery of a *Baiera* leaf adds substantially to this probability. A comparison of the Tanga plants with some of those described by Zeiller[2] from the Permian (Autunian) of France might create the impression that an age earlier than Triassic should be assigned to the African florule. The genus *Baiera* to which, on the evidence of leaf form alone, the specimen represented in Pl. XIX, Fig. 1, is referred, is represented in the French flora. Some of the coniferous branches included in *Voltziopsis* are similar to French Permian specimens assigned to *Walchia*. On the other hand, having regard to negative evidence—the absence of typical Permian genera—and to resemblances to Triassic species mentioned in the descriptive part of this paper, I am disposed to give preference to a Triassic age, probably Upper Triassic.

EXPLANATION OF PLATES XIX AND XX.

The photographs were taken by Dr. T. M. Harris and by Mr. E. T. Scott.

PLATE XIX.

Fig.
1.—*Baiera tanganyikensis* sp. nov. Half nat. size.
2.—*Cupressinocladus Harrisi* sp. nov. × 2.
3.—*Desmiophyllum parringtoni*. Nat. size.
4.—*Voltziopsis africana* sp. nov. × 2.
5.—*Voltziopsis* sp. Nat. size.

PLATE XX.

6.—*Desmiophyllum* sp. Nat. size.
7.—*Desmiophyllum* sp. Nat. size.
8.—*Cupressinocladus harrisi*. × 2.
9.—*Voltziopsis* sp. × 2.
10.—*Voltziopsis* sp. Nat. size.

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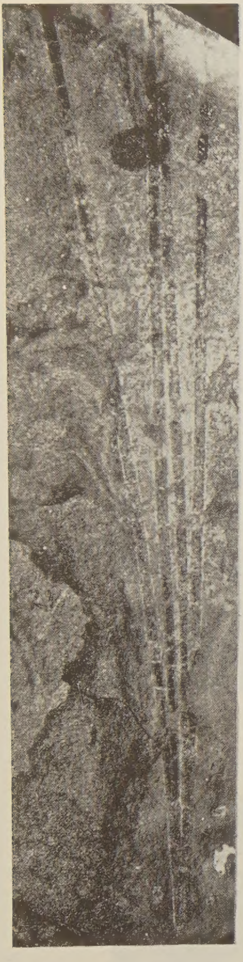
[1] Teale, E. O., "Provisional Geological Map of Tanganyika with explanatory notes," *Geol. Surv. Dept. Bull.*, No. 6.

[2] Zeiller, R., *Bassin houiller et Permien de Blanzy et Creusot*, Paris, 1906.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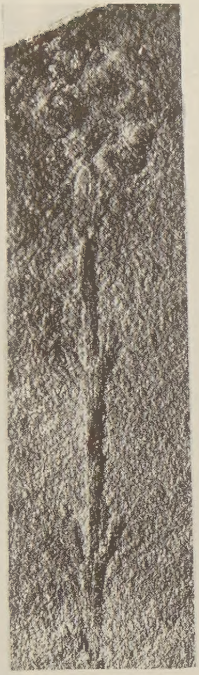
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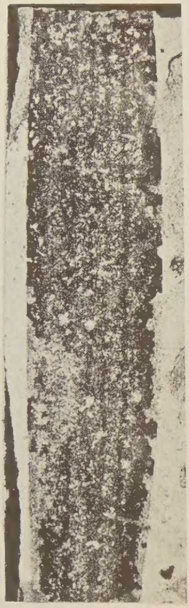
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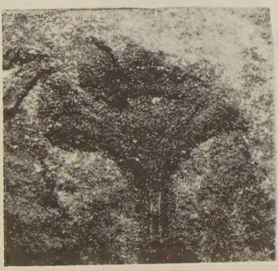
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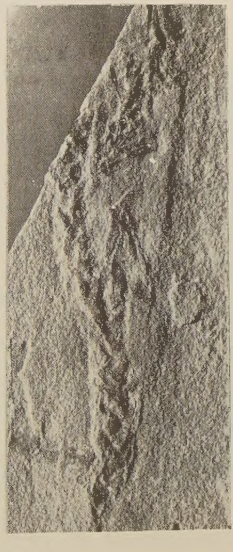
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FIG. 1, BAIERA; FIG. 2, CUPRESSINOCLADUS; FIG. 3, DESMIOPHYLLUM; FIGS. 4, 5, VOLTZIOPSIS.

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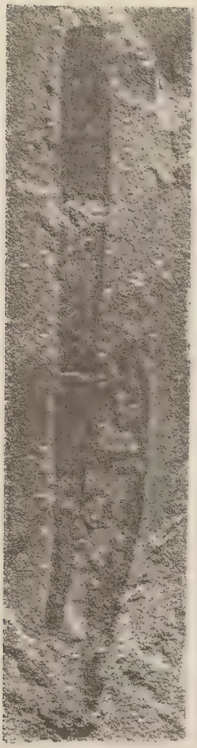

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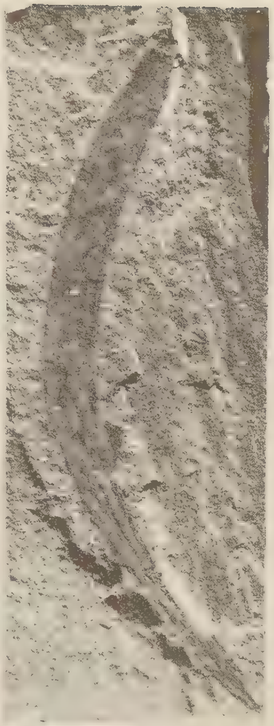

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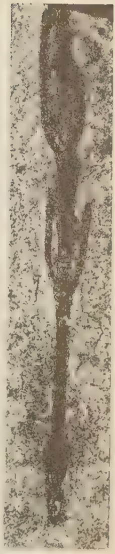

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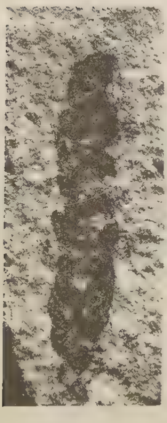

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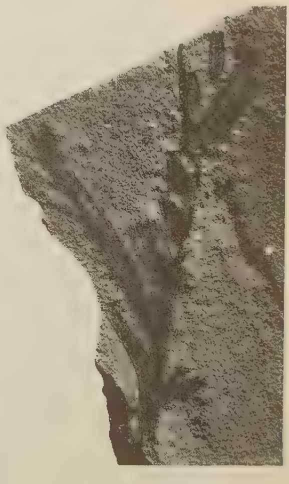

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FIGS. 6, 7, DESMIOPHYLLUM; FIG. 8, CUPRESSINOCLADUS, FIGS. 9, 10, VOLTZIOPSIS.

Notes on some Fossil Echinoids.

By Th. Mortensen.

(PLATES XXI and XXII.)

FOR a long period it was customary to base Echinoid classification exclusively on the characters of the test alone. It was not until the beginning of this century that other characters were also taken into consideration, starting with my work on the "Ingolf" Echinoidea I, 1903, in which I pointed out that characters of great classificatory value were found also in the structure of the pedicellariae and spicules. Through using these characters it was found that the numerous forms of Regular Echinoids, referred on account of the great uniformity of their test-characters to some few large "genera", e.g. *Echinus*, *Strongylocentrotus*, *Cidaris*, in reality belonged to a number of various generic types, even to different families. In the following year, 1904, in my "Siam" Echinoidea, I pointed out that also the structure of the teeth was of primary classificatory importance, this being further worked out by Jackson, 1912, in his *Phylogeny of the Echini*, where the characters of the whole dental apparatus were found to afford characters of the greatest importance, and where the excellent names *Aulodonta*, *Stirodonta*, and *Camarodonta* were coined, names which will have to be adopted in Echinoid classification.

The use of the microscopical characters of the pedicellariae in Echinoid classification was violently objected to, especially from students of fossil Echinoids, these finer structures being, of course, as a rule not observable in the fossils. The opposition was even carried to the absurd point of maintaining that, since these microscopical characters are not to be found in the fossils, it is not permissible to use them in the classification of the recent forms either, and that classification of Echinoids on the whole must be based on the characters of the test alone. No need of discussing such absurdity any longer! Classification, of course, must be based on *all* characters, according to their relative value as found through the study of the recent forms, where we have access to examining all the various characters. And we must then make the best we can out of the fossils, of which, as a rule, the finer microscopical characters are not to be made out.

It is a very fortunate fact that in various groups, as in most of the Irregularia and several of the Stirodonta, the microscopical characters are not of primary importance. But for a great number of the Regularia it is a fact that we cannot by means of the characters of the test alone decide to which genus, or even to which family or order they belong (although we may be perfectly able to recognize the species). In such cases we must admit our ignorance and leave such forms *incertae sedis*—until some day we may have the good fortune of discovering the decisive characters on some specimens which, through exceptionally favourable circumstances, have been so preserved as to show these characters.

Since I took up the study of fossil Echinoids, necessitated through my plan of working out a monograph of the Echinoidea, comprising both fossil and recent forms, I have been eagerly on the look-out for specimens of fossils which might give information of such characters of classificatory importance, as especially the lantern and the pedicellariae. Some results of great interest have already been obtained, as set forth in my paper " Sur les affinités de *Pseudodiadema* et de quelques autres Echinides fossiles " (*Bull. Soc. géol. France*, **5**, ii, 1933, 431–440). Since then a good deal more has been achieved, important material having very kindly been supplied to me from various sources ; the results of these later studies will be incorporated in Part II of my Echinoid Monograph.

During a recent visit to England in September, 1933, I had the privilege of looking over the splendid collections of fossil Echinoids in the British Museum, London, and in the Sedgwick Museum, Cambridge, with the special object of looking for specimens with the smaller spines preserved in situ, so that there might be hope of finding in these specimens also other structures of importance for classification, particularly the dental apparatus and pedicellariae. A good deal of the results obtained will be included in the forthcoming Part II of my Echinoid Monograph ; but some observations relating mainly to Cidarids, and thus not to be dealt with in the said Part II, I intend to deal with in the present paper.

I beg to tender my most sincere thanks to Dr. W. D. Lang, Keeper of the Geological Department of the British Museum, and to Mr. A. G. Brighton, Curator of the Sedgwick Museum, for giving me access to the said collections, and to Mr. Leslie Bairstow, for his ever-ready help in my researches at the British Museum. My special indebtedness to my friend, Professor H. L. Hawkins, Reading, may be gathered from Section 5 of the present paper. Also to Professor F. Broili, Munich, and to Professor Hennig, Tübingen, my best thanks are due for material sent me for study, as set forth in Section 4 of this paper.

1. A MIOCIDARIS FROM THE LIAS OF ENGLAND.

In the collection of the British Museum I found a small Cidarid from Lyme Regis (Cat. No. E 2020), which, although in a rather fragmentary condition, at once roused my interest, some of the interambulacral plates lying inside out and showing the adradial edge very distinctly bevelled and serrate (Fig. 1). It was clear at once that this was a *Miocidaris*, and as this is the first find of a *Miocidaris* in English Lias deposits, the specimen is of interest already for this reason ; moreover, it has both primary and secondary spines preserved. Quite a number of species of this genus have already been made known, some of them, e.g. *Miocidaris lorioli* Lambert & Thiéry, and *M. miserabilis* (Quenstedt), also with both primary and secondary spines preserved; but so much interest attaches to this, the most primitive type of true Cidarids, that any addition to our knowledge of it is of importance. As Dr. Bather, to whom we owe the important observations on the genus *Miocidaris* in his eminent work, *The Triassic Echinoderms of Bakony*, was not willing to undertake the study of this specimen, I thought it my duty to take it upon me, and the specimen then was sent me to Copenhagen, where I could study it at leisure.

Although in fragments, the specimen is fairly well preserved. It is an unfortunate circumstance that the deposit, in which it is embedded, is a very soft clay, very easily disintegrated with water; this makes further preparation of the specimen almost impossible, as the fragments of the specimen would run the greatest risk of being loosened from the matrix and probably fall to pieces. We must therefore be content with what can be seen of the specimen as it lies and so make the best of it.

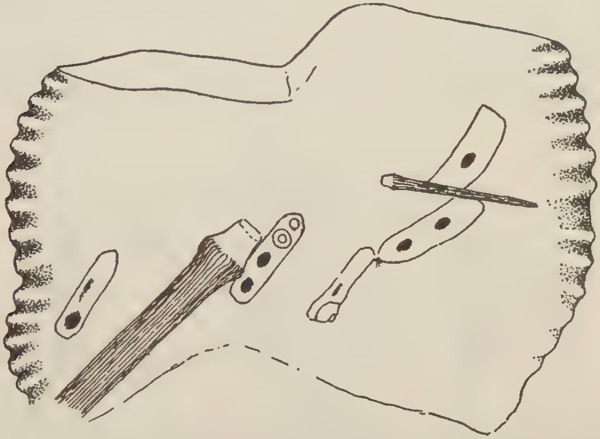

Fig. 1.—Part of an interambulacrum, seen from the inside, of *Miocidaris tenuispina* n. sp. Five isolated ambulacral plates are seen lying on it, as also a secondary spine and a primary spine, not yet fully formed and, accordingly, still without a collar. × 9. British Museum (Natural History), E 2020.

There seems to be no doubt but that this specimen represents a new species, which I shall designate as

Miocidaris tenuispina n. sp. (Pl. XXI, Fig. 2; Text-figs. 1–3.)

The *size* of the specimen must have been about 15 mm. horizontal and about 10 mm. vertical diameter; the general shape was apparently low hemispherical, not flattened on the oral side. Nothing of the aboral side to be seen.

The *interambulacral plates* have probably been 7–8; on the

3–4 lowermost ones the areoles are confluent, not much transversely elongate; only a narrow wall, with a single series of small tubercles, separates the larger ambital areoles. The areoles on the whole rather shallow. The primary tubercles very conspicuously crenulate. One of them has the appearance of being imperforate, which, however, is no doubt due only to preservation; the other tubercles are very distinctly perforate. Scrobicular tubercles rather distinctly mamelonate, not much larger than the extra-scrobicular tubercles. The median space of the interambulacra rather narrow, there being scarcely room for a single series of tubercles outside the scrobicular ones; on the adradial edge there are a few secondary tubercles in the corners between each two neighbouring scrobicular circles. Along the adradial edges of the interambulacrum the denticles appear like small granules. The median interambulacral line not naked or sunken.

Ambulacra.—Only five isolated ambulacral plates are preserved, lying on the part of an interambulacrum turning inside out, and only one of them shows the outside, the other ones turning the inside out or lying on edge—and, whereas the interambulacra lie almost loose in the matrix, so that the danger is that they should fall off, these ambulacral plates are cemented so strongly together with the interambulacrum on which they lie that they cannot be prepared off. But the single plate lying in the right position seems clearly to show that it carries two tubercles, viz. one on the perradial side of the marginal tubercle. The shape of the plate is rectangular, not ovoid (Fig. 1). The pores appear to bave been simple, not conjugate.

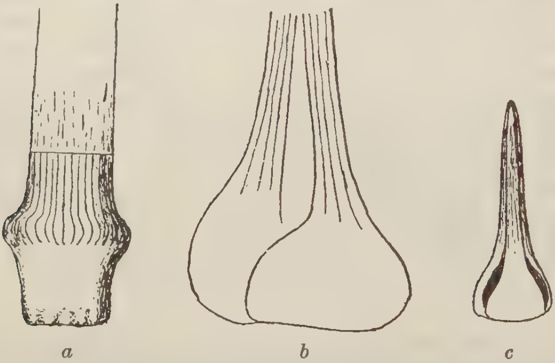

Fig. 2.—*Miocidaris tenuispina.* The basal part of a primary spine, showing the collar (*a*); basal part of a large pedicellaria (*b*), and a small tridentate pedicellaria (*c*). *a* × 12; *b* and *c* × 30. British Museum (Natural History), E 2020.

Spines.—The *primary spines* are long and slender, tapering, the longest one ca. 28 mm. The shaft is smooth and shining, only in the distal fourth part there is a faint indication of low rugosities, arranged longitudinally. The collar of moderate length (Fig. 2*a*).

Some of the spines are finely longitudinally striated, without collar; It is clear that they are young spines which have not yet formed the cortex layer. In section the primary spines show the typical Cidarid structure (Fig. 3).

The *secondary spines* are ca. 4 mm. long, very slender, setaceous.

In two places are seen pedicellariae; one of them (Fig. 2*b*) is a large form evidently of the tridentate type; unfortunately, it is not well enough preserved for showing its shape definitely, but it appears to resemble very much the pedicellariae of *M. lorioli*, as figured by Lambert & Thiéry (*Essai de Nomenclature raisonnée des Échinides*, pl. i, 9–10). The other (Fig. 2*c*) is only a small one, but well preserved; it is clearly a small tridentate pedicellaria. They are finely striated longitudinally.

Affinities.—It is clear that this species cannot be identical with any of the better known species of *Miocidaris*, like *M. lorioli* Lambert and Thiéry, *M. miserabilis* (Quenst.), *M. amalthei* (Quenst.), or *M. dubari* Lambert. From the first it is very clearly distinguished by the much narrower median interambulacral space and by the character of the primary spines. (The secondary spines of *M. lorioli* would seem to be setaceous, as in the present species, but much shorter.) *M. miserabilis* (cf. Lörcher, *Neue Seeigelfunde a. d. Jura Würtembergs. N. Jahrb. f. Mineral. Beilagebd.*, 64, ii, 1930; Taf. xvii, 1, *a–h*) has broad, flattened secondary spines and is thereby very clearly distinguished from the present species. *M. amalthei* (cf. Lörcher, op. cit., Taf. xix, 3 *a–b*) and *M. dubari* (cf. Lambert, "Echinides du Lias du Moyen Atlas Marocain," *Service des Mines et de la Carte Géologique du Maroc. Notes & Memoires*, xvii, 1931, 11, pl. i, 1–6) differ both by the character of the interambulacra and the primary spines from the present species. Among the other species hitherto described *M. Keyserlingi* (Geinitz) (cf. Bather, "Eocidaris and some species referred to it," *Ann. Mag. Nat. Hist.* (8), iii, 1909, pl. i, 8), as well as *M. verrucosa* Bather, *M. plana* Bather (cf. Bather,

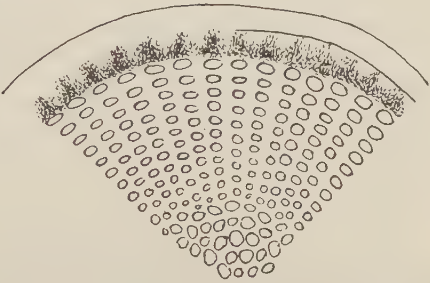

Fig. 3.—Part of transverse section of a primary spine of *Miocidaris tenuispina*. × 100. British Museum (Natural History), E 2020.

" Triassic Echinoderms of Bakony," 1909, pl. vi, 153–6 ; vii, 157–9), and *M. timorensis* Bather (cf. Bather, " Triassic Echinoderms of Timor," *Paläontologie von Timor*, xxx, 1929, pl. cclvii (i), 18–20) differ very clearly from the present species in the character of their interambulacra [1] ; this would also seem to hold good for *M. cassiana* Bather and *M. subcoronata* (Münster). Other imperfectly known species, like *M. arietis* (Quenstedt), *M. martini* (Cotteau), *M. pilosa* (Cotteau), *M. psilonoti* (Quenst.), and *M. praeteritus* Lamb. & Thiéry, differ by their thorny or granulated spines from the English species. One, *M. turneri* Lörcher (Lörcher, op. cit., p. 261, Taf. xix, 4 *a–c*), based on a single, fragmentary interambulacral plate and on a spine of which there is no certainty at all that it belongs together with the plate, is so very incompletely known that it would, indeed, seem to have been better not to burden science with such a " species ".

There is one more species, from the Lias of Germany, which must be taken into consideration as possibly identical with the species from the British Lias, viz. *Miocidaris minor* Lörcher (Lörcher, op. cit., p. 263, Taf. xviii, 2). It appears to resemble the British species rather much in the character of its interambulacra ; but its ambulacral plates have each only one tubercle, whereas the British species has—judging from the single plate lying in the right position—two tubercles to each ambulacral plate. This would seem to show beyond doubt that the two cannot be identical. (The spines of *M. minor* are unknown.) It seems then the only reasonable course to regard the specimen from Lyme Regis as representing a new species of the genus *Miocidaris*.

2. On the Genus *Tylocidaris*. (Pl. XXI, Fig. 1 ; Text-figs. 4–6.)

A very rich and partly finely preserved material of *Tylocidaris clavigera* (König) is found in the collections of the British Museum and the Sedgwick Museum, the study of which has enabled me to give some important additions to the knowledge of this aberrant Cidarid genus, *Tylocidaris*, so unique by its imperforate tubercles—a character so unusual in the Cidarids that one might almost be tempted to think it might not be a real Cidarid. The fact disclosed in my monograph of the Echinoidea, i, p. 486, that some of the upper primary tubercles are sometimes found to be perforate has, however, bridged over the gap between *Tylocidaris* and the other Cidarids. On the whole, there can, of course, be no doubt but that *Tylocidaris* is a true Cidarid which has only, in regard to the character of its tubercles, developed along a separate line so as to form a type of its own.

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[1] After this paper had been written I received from Professor Alph. Jeannet, Zürich, a " Note sur un Miocidaris nouveau " (B. Peyer, " Die Triasfauna der Tessiner Kalkalpen. VI," *Abh. d. Schweiz. Pal. Gesellsch.*, liii, 1933), in which is described a *Miocidaris hescheleri* n. sp. from a single specimen, preserved with its spines, much like the present specimen. It is, however, very different from the English *Miocidaris*, by the character of its ambulacra, spines, and particularly by having a series of large, crenulate tubercles outside the primary interambulacral tubercles. Jeannet makes it a subgenus of *Miocidaris*, *Serpianotiaris*, leaving it undecided whether it should perhaps rather form a separate genus. There can, in my opinion, be no doubt but that it should really form a separate genus. This outer series of tubercles, as also the absence of a collar on the primary spines, and the unusual character of the ambulacra, distinguish it so markedly from *Miocidaris* that one might, indeed, be tempted to suggest that it should perhaps rather form a separate family.

The new observations here given refer to the characters of the peristome, the apical system, and the secondary spines.

Peristome.—Wright, in his "British Fossil Echinod. from the Cretaceous Formations", pl. v, 4, figures part of the peristome of *T. clavigera*, showing the peristomial plates arranged as in typical Cidarids. It is, however, not clearly shown in this figure which of these plates are ambulacral, which interradial. In the specimen 46766 of the British Museum (not the same as that from which the said figure of Wright was drawn), I find the peristomial plates to be disposed as shown in Fig. 4. As appears from this figure, the ambulacral plates are disposed in irregular double series, and *there are no interradial plates*. The three plates marked with a × do not show any pore, but it is perfectly clear from their place on the peristome that they are not homologous with the interradial peristomial plates of other Cidarids; if such plates were present they should be placed off the interradial midline, but here no such plates are found.

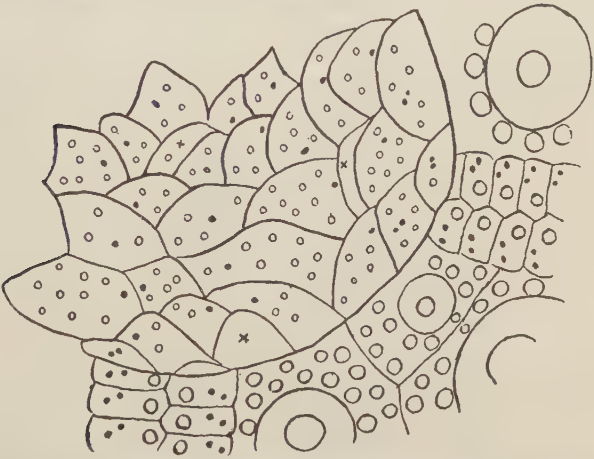

Fig. 4.—Part of peristome of *Tylocidaris clavigera* (König). On the plates marked × no pores could be observed. × 6. British Museum (Natural History), 46766.

The peristomial plates are rather high, with tubercles scattered irregularly all over their surface, not arranged in a series along the adoral edge of the plates as is otherwise the rule in Cidarids. In regard to the peristomial plates *Tylocidaris* accordingly is a very specialized type, as it is in regard to the specialized character of its primary tubercles.

Apical system.—A very perfect apical system of *Tylocidaris clavigera* is figured by Wright in pl. v, 3 (op. cit.). A specimen in the Sedgwick Museum (B. 20,002) has also the apical system partly preserved, but the plates are somewhat dislocated and lie in various positions. This discloses a very remarkable feature of the genital plates, viz. a very conspicuous striation on the sides of the plate which join the neighbouring genital plates (Fig. 5). The striation is found only on these edges, not on any of the other edges of the plate, and apparently not on any of the other plates of the apical system. The same striation is found also on the genital plates of *Tylocidaris baltica*, as I have been able to substantiate on material of this species collected by Dr. Brünnich Nielsen.

Having discovered this curious feature, I looked over a good number of the recent Cidarids and found a similar structure in *Cidaris cidaris*, on the same edge of the genital plates, though not nearly as distinctly developed as in the present species; in none of the other Cidarids examined did I find any trace of this structure.

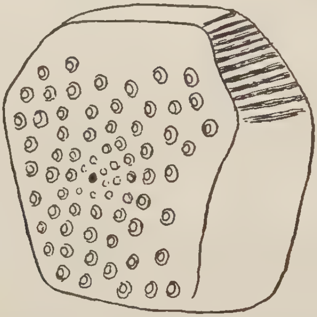

FIG. 5.—Genital plate of *Tylocidaris clavigera* (specimen B 20002; Sedgwick Museum, Cambridge), in half-side view; showing striation on the side that joins the neighbouring genital plate. × 9.

The meaning of this structure may not improbably be to consolidate the connection between the plates. Although recalling in some way the striation of the adradial edge of the interambulacral plates in *Miocidaris*, it is not at all comparable therewith. In *Miocidaris* it is a primitive structure inherited from its ancestors with the imbricated plates. In *Tylocidaris*, as well as in *Cidaris*, both highly specialized types, it must represent a new acquisition, a specialized feature.

Secondary Spines.—Although specimens of *Tylocidaris clavigera* with the primary spines preserved more or less completely in situ are not at all uncommon, specimens with the secondary spines preserved appear to be very rare, and no such specimens have been figured till now. I was therefore very interested in finding in the Sedgwick Museum a specimen (B. 20,003) with the secondary spines preserved to a great extent in situ, as shown in Pl. XX, Fig. 1.

The secondary spines[1] of this species prove to be very unusual, in being conspicuously rugose or thorny on the outer side, the thorns being arranged in transverse series as shown in Fig. 6*b*. This holds good of the scrobicular as well as the ambulacral spines. The miliary spines are club-shaped, somewhat rugose, but, in accordance with their much smaller size, not as coarsely as in the larger secondary spines, and with no distinct arrangement of the rugosities in transverse series (Fig. 6*c*). There are, however, all transitions from the larger, transversely rugose spines to the more simple, club-shaped, small spines. In another specimen (B. 20,001) with some few secondary spines preserved these are less rugose than in the described specimen, but still distinctly of the same type.

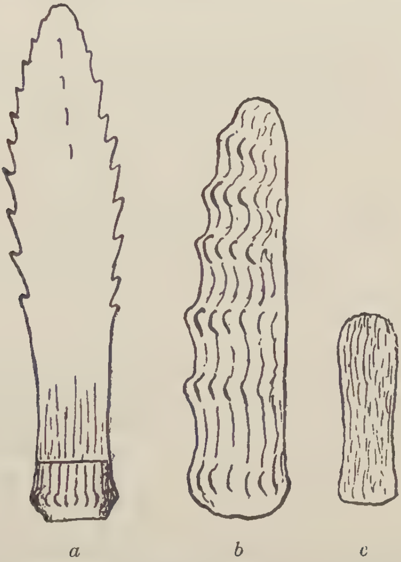

Fig. 6.—Spines of *Tylocidaris clavigera* (specimen B 20003, Sedgwick Museum, Cambridge). *a*, Oral primary spine; *b*, secondary spine, in side view; *c*, miliary spine. *a* × 12; *b* and *c* × 30.

It is rather curious that, while the secondary spines are so marvellously preserved in specimen B 20003 the larger primary spines are not preserved; only part of one of the characteristic club-shaped spines lies in the matrix broken off the specimen. But then the oral primary spines are partly well preserved ; they are somewhat flattened, spatulate, with strongly serrate edges (Fig. 6*a*), strongly contrasting with the club-shaped ambital primary spines of this species. Such spines are also figured in Wright, op. cit., p. 74, fig. 2, these figures, as well as the one of the secondary spine, being due to Rev. T. Wiltshire.

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[1] A figure of such a spine is given in Wright's *Monograph of the British Fossil Echinodermata from the Cretaceous Formations*, p. 74, fig. 3. I am indebted to Mr. Brighton for calling my attention to this figure, which I had overlooked.

That the peculiar character of the secondary spines of *Tylocidaris clavigera* is only a specific character, not a character of the genus *Tylocidaris*, is evident from the fact that the secondary spines of *Tylocidaris baltica* are of the simple, flattened shape usual in Cidarids. This information I owe to Dr. Brünnich Nielsen, who has found such spines in washings of the chalk immediately surrounding a specimen of this latter species.

It was a great disappointment to me that in the said specimen of *T. clavigera* with the secondary spines so finely preserved not a single pedicellaria could be found. Also Dr. Brünnich Nielsen was disappointed in finding no pedicellariae in the washings of the specimen of *Tylocidaris baltica* which yielded the secondary spines of that species. There is thus still no certainty that the peculiar type of pedicellariae discovered by Brünnich Nielsen (cf. my paper, " Contributions to the Knowledge of the Cidarids," *Mem. R. Ac. Sc.*, Copenhagen, **9**, iv, 1932, 178) does really belong to *Tylocidaris*. Otherwise the genus *Tylocidaris* is now almost as completely known as the recent Cidarids (excepting, of course, the colour and the spicules of the tubefeet and the internal organs).

In a recent publication, Else Schönfelder, " Die Kreideanhäufungen im Geschiebemergel d. nördl. Schleswig, ihre Fossilführung u. geologische Bedeutung " (55, *Jahresber. d. Niedersächs. geol. Vereins*, Hannover, 1933), a Cidarid spine (Taf. xiv, 40), which corresponds very well with *Cidaris pistillum* Quenst., is claimed to be a pathological form of a spine of *Tylocidaris clavigera*. " Es ist deutlich erkennbar, dass der obere Teil des Stachels eingesunken ist, wahrscheinlich infolge einer Infektion zu Lebzeiten des Tieres." This is a perfectly wild suggestion, due evidently to insufficient general knowledge of Cidarids. A pathological transformation to such extent as this would be, if it were really derived from a normal *Tylocidaris clavigera*-spine, is quite unthinkable ; nothing at all comparable of pathological transformations has ever been found in all the numerous recent forms—and here it would even be of quite common occurrence ! As if a Cidaris spine were like a theatre dagger that could be pressed into itself ! Normal spines of a similar appearance, on the other hand, are of quite common occurrence also in recent forms, particularly in the genus *Goniocidaris*. The *Cidaris pistillum*-spines are likewise perfectly normal spines ; nothing pathological about them !

Also another Cidarid spine is figured as pathological (*Taf.* xiv, 41). It is a fragment of a perfectly typical spine of *Cidaris hagenowi* Desor (cf. J. P. J. Ravn, " De Regulaere Echinider i de danske Kridtaflejringer," *Mem. Acad. Copenhague*, **9**, i, 1928). (Pl. XXII, Figs. 1–8.)

3. *Cidaris perornata* Forbes.

In a specimen in the British Museum (46780) from the Chalk, Bromley, I have found pedicellariae well preserved. They are large, 3–4 mm. long, with rather sharply keeled blades (Pl. XXII, Figs. 1–2). One isolated valve lies so as to show the inside. Along the middle of the blade there is a somewhat elevated keel, which seems to have an impression along the midline (Pl. XXII, Fig. 3). This makes it quite probable that this pedicellaria is of the globiferous type. Whether the pedicellariae represented in Pl. XXII, Fig. 1–2 belong to this same type, or they are perhaps rather tridentate pedicellaria I do not venture to state definitely—for ascertaining this it would be required to examine the isolated valve from the outside and the valves of the whole pedicellariae from the inside—which I could not do. But anyhow it is interesting now to have found the pedicellariae in this fossil Cidarid.

4. *The Lantern of some Cidarids.*

Some time ago Dr. R. Rutsch, Curator of the Palaeontological collection of the Natural History Museum of Basel, sent me (together with a specimen of *Stomechinus perlatus* with the lantern preserved)[1] a specimen of (*Cidaris*) *Paracidaris florigemma* (Phillips) with the lantern preserved. The specimen is of considerable historical interest, being the one figured by Andreae in his *Briefe aus der Schweiz, nach Hannover geschrieben in dem Jahre* 1763, Taf. I, Fig. H. Dr. Rutsch very kindly gave me permission to remove as much of the test as would be necessary for preparing clear the upper part of one of the pyramids.

In Fig. 7*a* is shown the outlines of the pyramid, showing the epiphysis to be very small and low, and the upper part of the pyramid rather broad, forming almost a straight line.

From the Director of the Palaeontological Collection of Munich, Professor F. Broili, I have received a specimen of *Plegiocidaris elegans* (Münster) with the lantern preserved. As in *Paracidaris florigemma* the epiphysis of this species is low, but the whole shape of the pyramid (Fig. 7*b*) differs rather conspicuously from that of the former species.

In Quenstedt's *Petrefactenkunde Deutschlands* are figured some Cidarids with the lantern preserved, e.g. Tab. 65, 4, 6 ; 66, 1. The director of the Geological-Palaeontological Institute, Tübingen, Professor Dr. Hennig, very kindly lent me these specimens for examination, for which favour I beg to express my sincere thanks. I found, however, that I could do nothing with them beyond what

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[1] The description of the lantern of this specimen will be given in Part II of my Echinoid Monograph.

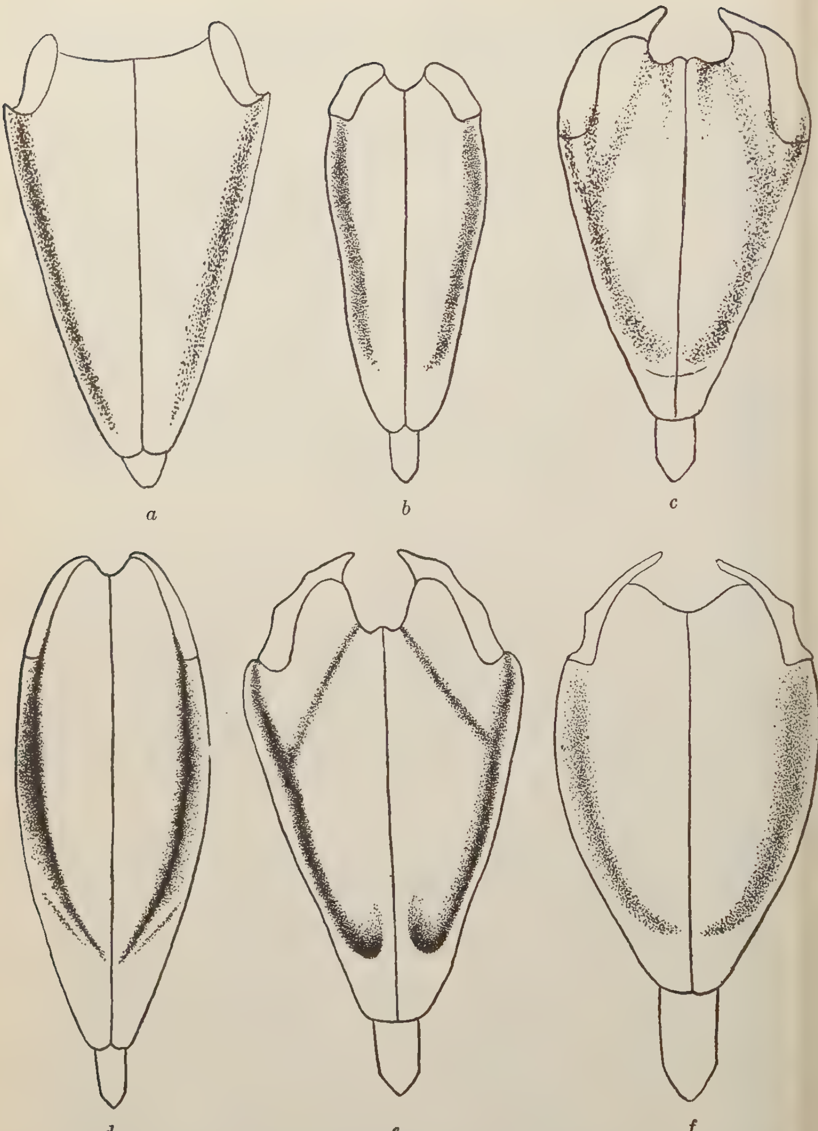


FIG. 7.—Dental pyramid of various Cidarids. *a*, *Paracidaris florigemma* (Phillips) × 3; *b*, *Plegiocidaris elegans* (Münster) × 5; *c*, *Cidaris cidaris* (Linn.) × 3·5; *d*, *Eucidaris metularia* (Lamk.) × 4; *e*, *Goniocidaris tubaria* (Lamk.) × 4; *f*, *Acanthocidaris curvatispinis* (Bell) × 6. *a*, Natural History Museum, Basel; *b*, Palaeontological Collection, Munich; *c–f*, Zoological Museum, Copenhagen.

had already been done by Quenstedt; to make out the shape of the epiphysis in these specimens does not seem possible.

It occurred to me that it might be of some interest to study the shape of the lantern also in recent Cidarids; perhaps there might be found structural differences of some interest. I give here figures of a dental pyramid, with its epiphysis of four recent Cidarids, viz. *Cidaris cidaris* (Linn.) (Fig. 7*c*), *Eucidaris metularia* (Lamk.) (Fig. 7*d*), *Goniocidaris tubaria* (Lamk.) (Fig. 7*e*), and *Acanthocidaris curvatispinis* (Bell) (Fig. 7*f*).

As seen by these figures there is really quite a good deal of variation in the shape of the pyramids as well as in that of the epiphysis—particularly that of *Eucidaris metularia* is conspicuously different from that of the others.

It is, of course, not the place here to go deeper into details with regard to the dental apparatus of recent Cidarids; the said four examples may suffice to show that here is a subject well worth being taken up for a more detailed study. Results of great morphological value are hardly to be expected; but we may well expect that the study of these details may in some way serve to check the results reached by the study of other characters and thus contribute towards consolidating the classification of this great family of Echinoids, a classification which offers many difficulties and has been the object of so much discussion.

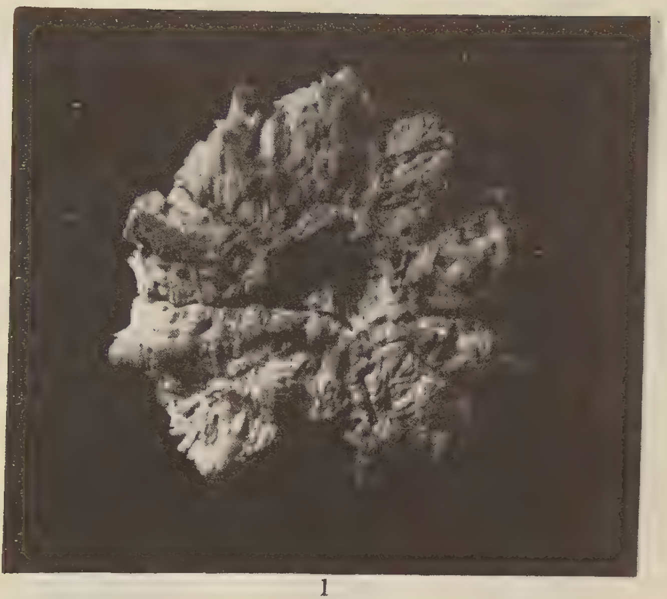
5. *On some Fossil Echinoid Pedicellariae.*

Some years ago I called on my friend, Professor H. L. Hawkins, Reading, who showed me in his fine collection of fossil Echinoids a tube containing a number of exceptionally finely preserved isolated valves of pedicellariae from the Frith Quarry, near Painswick. Professor Hawkins most kindly sent me this material to Copenhagen for a closer study, a favour for which I am greatly obliged to him.

The sample sent me proved to contain at least five distinct types of pedicellariae, as represented in Pl. XXII, Figs. 7–8. One of them, Pl. XXII, Fig. 7, is an ophicephalous pedicellaria, very much like the ophicephalous pedicellariae found in most regular Echinoids. The large form, Pl. XXII, Fig. 5, is evidently a tridentate pedicellaria, recalling rather much some pedicellariae of Echinothurids; this also holds good of the (broken) form with a median keel in the blade, represented in Pl. XXII, Fig. 8. The small form, Pl. XXII, Fig. 6, recalls the short tridentate pedicellariae of *Hemiphormosoma paucispinum* (to be described in the forthcoming Part II of my Monograph of the Echinoidea). These four types all resemble pedicellariae known from various recent Echinoids. But the form represented in Pl. XXII, Fig. 7, the most conspicuous of them all, differs markedly from all pedicellariae of recent Echinoids known to me. It is evidently of the tridentate type, but is unique in the blade being convex on the inside and set with serially arranged coarse knobs. That it must have been quite an active weapon is evident.

Having made a study of these pedicellariae, so remarkably well preserved, I wanted very much to see the locality where they were collected, and particularly to see, whether there might be any possibility of finding the Echinoids to which these pedicellariae belonged. Such an opportunity presented itself in the fall of last year, after the meeting of the British Association in Leicester. Professor Hawkins then most kindly took me on an excursion to Painswick, near Gloucester, in the neighbourhood of which is the Frith Quarry, and a number of other quarries in the Inferior Oolitie deposits. We found there the special layer from which the pedicellariae had been collected, viz. a 2–3 cm. thick layer of a soft, brown, earthy marl between the *Buckmani* grit and the Lower *Trigonia* grit (Bajocian) (cf. L. Richardson, *A Handbook to the Geology of Cheltenham and Neighbourhood*, Cheltenham, 1904). A fairly large sample of this layer I brought home for a closer examination. It was very easily disintegrated in water; the washed material was very carefully examined and found to contain numbers of fragments of Molluscs and Echinoderms, Ostracods, Foraminifera, etc. Especially numerous were isolated stalk-joints and segments of cirri of Crinoids, but also vertebrae and armplates of Ophiurids, plates of Asteroids, etc., were quite common. In the sample I found one, somewhat fragmentary, but perfectly recognizable, example of the large pedicellaria with the knobs—it being thereby proved that we had hit upon the exact place where all these pedicellariae had been collected.

The character of the deposit proves that it represents an old beach, corresponding exactly to what may be found on a sandy beach at a tropical or subtropical coast nowadays. The organisms, or fragments of organisms, that are found in it have been washed up by the waves. Accordingly there is not the slightest possibility of finding the Echinoids to which these pedicellariae belonged. It would no doubt be possible also in the beach-sand of recent seas to find isolated valves of pedicellariae, if a sufficiently large amount of material were washed and carefully examined. With the recent forms we might probably be able to identify the species of Echinoids from which such pedicellariae might have come, knowing all the species of Echinoids that occur off the coast from where the examined material came. With the pedicellariae from the beach formation of the Frith Quarry matters lie rather differently. We do not know the whole Echinoid fauna of the sea that washed that beach, and even if we had a complete list of the Echinoids of those seas we would not know with any degree of certainty to which of them the various forms of pedicellariae would belong—with one exception, however, and that, fortunately, the most interesting of them all, the one figured in Pl. XXII, Fig. 4. *There is, indeed, very great probability that it belongs to the genus Pelanechinus.* A comparison with the figure of the large tridentate pedicellariæ of this Echinoid figured in Pl. XXVIII, 3*a*, of Groom's paper " On some new features



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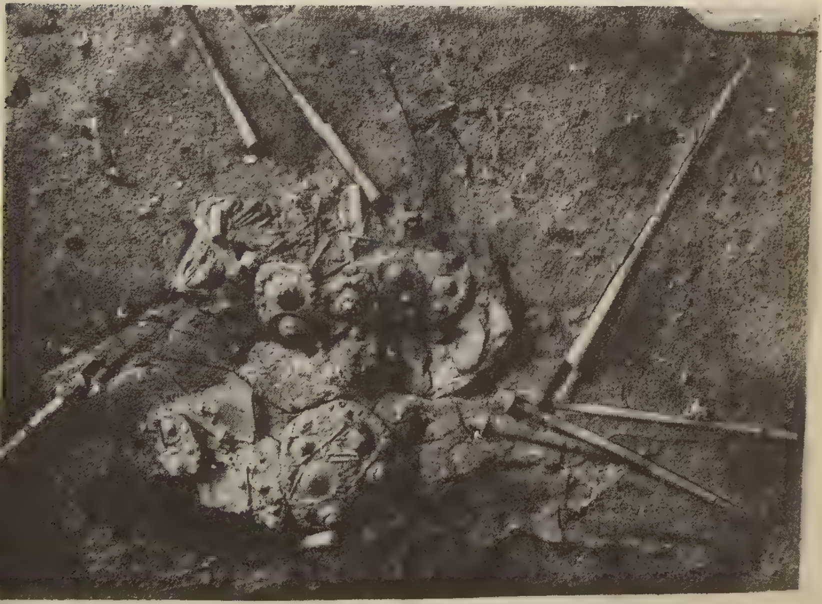

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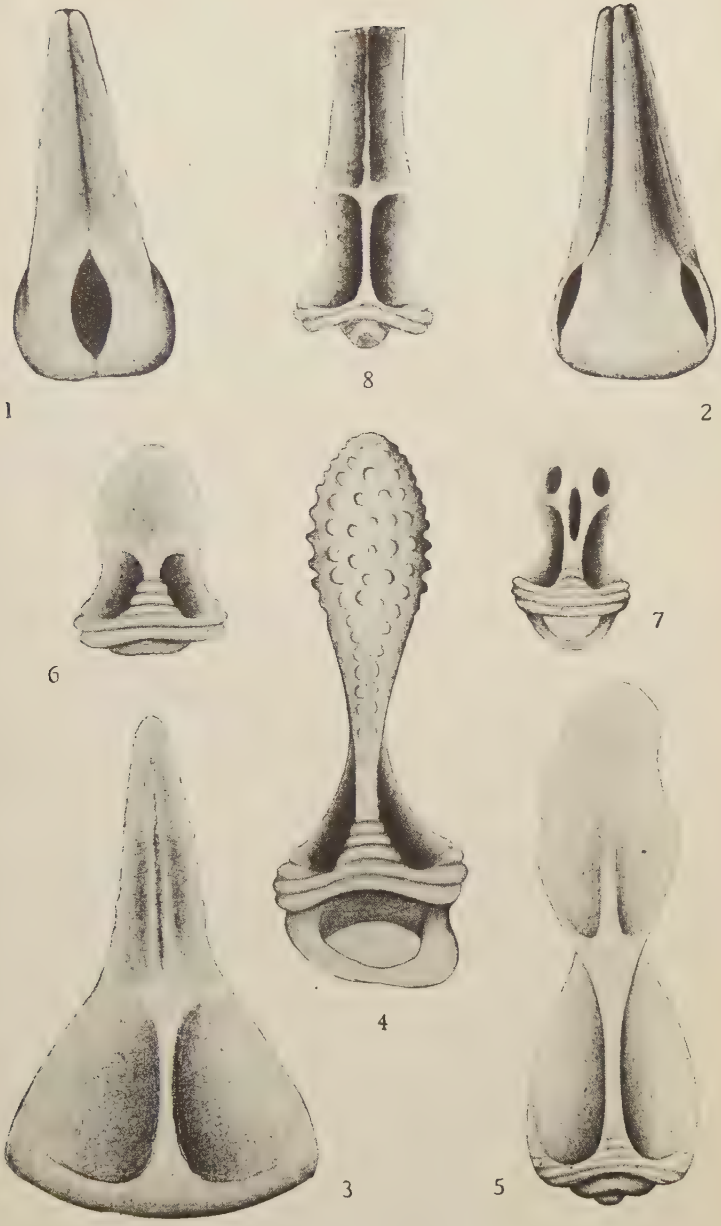
FIG. 1. TYLOCIDARIS CLAVIGERA. FIG. 2. MIOCIDARIS TENUISPINA.

[*To face p.* 406



PEDICELLARIAE OF ECHINOIDS.

in *Pelanechinus corallinus*" (*Quart. Journ. Geol. Soc.*, xliii, 1887) seems to leave no doubt of the pedicellaria from the Frith Quarry being really the same.

According to the kind information of Professor Hawkins, the Coral Rag at Calne, from which Groom's fine specimen of *Pelanechinus corallinus* came, belongs to the Corallian (probably the Sequanian). It is therefore improbable that the pedicellariae from the Frith Quarry, belonging to the Bajocian, could be the same species as *Pelanech. corallinus*. But even if it be not the same species, the resemblance between the large Frith form of pedicellariae with the form figured by Groom is so great that one would seem justified in stating them to belong to the same genus.

None of the other pedicellaria types from the Frith Quarry can be identified with any of the other pedicellariae of *Pelanechinus* figured by Groom. But the result of having the said remarkable type of pedicellariae identified as belonging to the notable genus *Pelanechinus* is of very considerable interest and shows that it is not quite futile to expect that careful investigations will disclose these minute, but highly important, structures also in other fossil Echinoids.

EXPLANATION OF PLATES XXI AND XXII.

PLATE XXI.

FIG.

1.—*Tylocidaris clavigera* (König). Specimen with the secondary spines preserved in situ. Aboral side. × 2. (Specimen B 20003, Sedgwick Museum, Cambridge.)

2.—*Miocidaris tenuispina* n. sp. Type-specimen. × 2. British Museum (Natural History), E 2020.

The photos were taken by Dr. Chr. Poulsen, Mineralogical Museum, Copenhagen, to whom I beg to tender my sincerest thanks for this most valuable assistance.

PLATE XXII.

1–3.—Pedicellariae of *Cidaris perornata*. 1–2: Tridentate pedicellaria in two different views. 3: Valve of globiferous (?) pedicellaria from the inside. × 12.

4.—Valve of tridentate pedicellaria of *Pelanechinus* sp. from the inside; Frith Quarry. × 53.

5–8.—Valves of various types of pedicellariae from the Frith Quarry. 5: × 30. 6–8: × 53.

The Quaternary Changes of Ocean Level: Cause and Consequences.

By Cosmo Johns.

CONTENTS.

INTRODUCTION.
MOVEMENTS OF THE LITHOSPHERE.
CHANGES OF OCEAN LEVEL.
APPLICATION OF CRITERIA.
CONCLUSIONS.

INTRODUCTION.

IN a preliminary article (1) [1] dealing with the British Quaternary strand-line oscillations it was shown that unexpected correlations had emerged as a result of the methods employed. Of the possible assumptions the only one to prove workable was that there had been, during Quaternary time, a temporary lowering of ocean level of 1,000 metres or more. The graphs left no reasonable doubt that if the ocean level had moved in the way assumed the Mindel-Riss interval of Penck's Alpine sequence must be equated with the major glaciation of North-West Europe and the British Isles. In order to test this, the only assumption made, it was applied to the coral reef problem (2) and there it was successful in offering what should be an acceptable solution. It was surprising to find that Darwin had actually used an apparent rise of ocean level, of the same order of magnitude, to illustrate his own theory of subsiding islands. The success of the postulate when faced with the coral reef problem was held to have invested it with a high degree of probability. It was pointed out, however, that changes in ocean level of that magnitude could best be explained by the sinking of the ocean floor, and the North Pacific Ocean was indicated as the probable position. The cause of the changes of ocean level will now be investigated and then its consequences discussed in the light of ascertained facts.

In what follows the evidence for locating the sunken area in the position suggested will be discussed. Its capacity must be equal to a volume of water with the area of the oceans, and one kilometre or more in depth. It will be found that not only had vertical movements taken place, but that the inflow of deep-seated material as the spheroid of rotation was restored must have resulted in horizontal movement of parts of the lithosphere. The influence of the world-wide oscillation of strand lines, resulting from the movements of the ocean floor, in causing climatic changes and altering the relation of the sea and land areas will be noticed and criteria applied. When this has been done the original raised beach curve can be revised in the light of the new findings and greater precision given to the graph depicting the relation of the North African pluvial periods to the glaciation of the Alps and of North-West Europe. The final test of the validity of the theory is that it should offer a reasonable explanation of as many long-standing and unsolved problems as possible without creating new ones. At every stage of the discussion when conclusions have been reached, they will be followed by a rigorous test of their consequences.

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[1] The numbers in parentheses refer to References at end of article.

Before doing this a brief reference must be made to the present state of opinion among workers on the geology and archaeology of the Quaternary period. The problems are often linked ones, for the emergence of our ancestors as the only tool-making animals furnishes evidence which has been used to check the geological findings. The state of opinion can only be described as conflicting and confusion of thought is not uncommon. Gregory (3) gave an account of the marked difference of opinion that exists on the Continent of Europe; Boswell (3) has discussed the position of British workers. Antevs (4), who prepared the maps for the symposium arranged by the Geological Society of America, laments the difficulty he experienced owing to this lack of agreement. The archaeologists are in no better case, and even show signs of losing faith in their own evidence. This conflict of opinion is reflected in the work of every committee, symposium, or formal discussion arranged in recent years. Hazzledine Warren (5) tabulated a dozen correlations that have been published by the leading authorities. As all differed only one can possibly be correct, and a critic would be forgiven if he harboured a suspicion that all might be wrong. If active controversy is absent it is because no correlation put forward has succeeded in enlisting any substantial measure of support. If, and when, a solution does emerge it would appear that there would still remain a problem that only a competent psychologist could deal with effectively.

The graphic method used in the present investigation, and described in the preliminary account, does at least reduce to a minimum, if it does not entirely eliminate, the psychological factor. It is one of measurement and records the movement of land, sea, and air, against time. It measures the time as a percentage of a geological period, though the actual duration of that period is unknown. The personal element cannot be eliminated entirely, for data must be selected, but no question of correlation arises until the graphs are completed. All that is accomplished is to devise a frame into which the various Quaternary episodes must fit if the facts have been ascertained and the frame correctly designed. It is not surprising that the correlations resulting were unexpected in view of the prevailing conflict of opinion.

Movements of the Lithosphere.

In the second communication the North Pacific was suggested as the site of the part of the ocean floor which sank, and also that the consequent lowering of ocean level and the outburst of volcanic activity, which supplied the foundations on which the coral reefs are cemented, were twin effects that followed the collapse of the ocean floor. The considerations that led to that conclusion will now be discussed. It is noteworthy that while the reefs have been the subject of controversy for the greater part of a century, the geological history of their foundations has failed to arouse much interest. That they are volcanic in origin is generally agreed. The only alternative is to regard the coral reefs as resting on the summits of submerged folded chains of mountains; for this there is not the slightest evidence. With the exception of the Loyalty Islands and Mangaia in the Cook group, where the limestones have been determined as of Miocene age, the reefs are late Quaternary and their foundations most probably Quaternary also. W. M. Davis suggested that the Miocene fauna might have survived in the Pacific, but a preferable explanation is that we are dealing with more than one generation of islands. A few would be Tertiary age, but the vast majority are of Quaternary date. The problem is how to account for such a violent outburst of volcanic activity over such a vast expanse of ocean floor, extending as a wide belt for one quarter of the circumference of the globe measured on a great circle, of a date so recent that the reefs which grew on the foundations thus provided are all of Quaternary age.

Dana (6) has shown that a line drawn from Pitcairn Island in the extreme south of the coral reef belt towards Japan, trending N. 56° W., can be regarded as the main axis of the region abounding in atolls, and that this line coincides with the mean trend of the many chains of islands. Another line starting from the same point but trending N. 70° W. serves as a useful boundary between one region where atolls are numerous, and another where they are rare except for a few near the line. Ardlt (7) found the mean trend to be N. 62° W. It is clear that these lines relate to a disturbed ocean floor where a large number of volcanos, arranged in definite trends, have built up the piles of rocks on the summits of which the atolls and other reefs now rest. This vast area must have been subjected to tensional and possibly more complex stresses. A line intersecting and normal to N. 60° W., the adopted mean trend line of the island chains, should point in the direction from whence the stress was applied.

At one end of this line we reach North America near its western sea-board. There happens to be another guide which should help in locating the sunken ocean floor; it is found in the important geodetic work of Heiskanen (8), whose formula makes the geoid a triaxial spheroid. He locates the equatoral protuberances in 18° E. and 172° W., and finds the minimum ellipticity to occur along longitude 72° W. The normal to the coral islands mean trend and Heiskanen's minimum ellipticity line thus both converge towards North America. It is therefore to the north that attention must be directed, even though the site indicated is at present occupied.

In a later communication (8) Heiskanen discusses the gravity determinations of Meinesz and their bearing on his theory. The significance of the important results obtained by Meinesz is referred to below.

Evidence has long been accumulating pointing to a former close connection of eastern North America and Greenland with North-West Europe. It is not intended to review the evidence here, extending as it does over long geological periods. It is only necessary to replace the regions in question, taking the edge of the continental shelf as a convenient, though not always the strictly accurate, boundary using a globe for the operation. No one who has done this and observed the excellent fit it makes, and gives due weight to the geological arguments, can retain any reasonable doubt as to the reality of a former connection. Perhaps the most convincing argument is to be found in Bailey's (9) illustrations of the intersection of the Caledonian and Hercynian fronts. But it is not in any one line of evidence that proof is to be sought. It is varied in character, weighty in substance, and cumulative in effect. The only real question is the date at which the displacement took place. From the evidence of the maximum extension of the Quaternary ice sheets on both sides of the Atlantic, the terminals of which register with precision when replaced, the main fracture would appear to have taken place about mid-Quaternary time, but dislocation probably started earlier. This is consistent with the occurrence of a significant number of American species (10) in the existing flora and fauna of North-West Europe. When the floor of the Northern Pacific collapsed that ocean was therefore much wider than it is now. Ample space is available for whatever area the depression may have possessed without giving it excessive depth. The order of its magnitude may be gathered from the relation between area and depth. If the effective area was one-tenth that of the oceans, then each kilometre that the ocean level was lowered must be multiplied by ten. If the ocean level movement was one kilometre, then the depression floor was 10 kilometres deep. If Brögger's 2,600 metres is confirmed, then the floor was depressed to the amount of 26 kilometres. Not an unreasonable amount when viewed on a true scale diagram and compared with the earth's radius.

In a recent seismological report (11) an interesting map of the Pacific Ocean was given showing an approximately oval curve with its axis intersecting the equator and its boundary defined by the epicentres of deep foci earthquakes. The axis of the curve lies north of, and roughly parallel to, the mean trend of the line used above to indicate the region abounding in atolls. The report asks " is this an old scar representing the detachment of the moon from the earth ? " It was thought that " the occurrence of so many epicentres round the shores of the Pacific lent some support to the idea ''. It would seem that the conclusion reached in the present investigation, which locates a collapse of the ocean floor in a widened North Pacific, not only serves the purpose for which it was intended, but offers a more probable explanation of the distribution of deep foci earthquake epicentres. When in addition it supplies the gravitational pull that enabled North America to swing round to its present position, its usefulness seems to be well established.

Before leaving the Pacific Ocean it is necessary to point out that the temporary lowering of ocean level by 1,000 metres, or more, is only the dominant movement. The sinking of a large area of ocean floor and its restoration by the inflow of deep-seated material to conform to the spheroid of rotation, could not have been a simple operation. Changes of level and horizontal movement of the lithosphere would occur in surrounding regions. The dominant movement of ocean level has been described, but in the course of the re-adjustment of the distorted lithosphere secondary changes of ocean level must have occurred in addition to that due to the abstraction of water to form ice sheets and its return to the ocean when the ice melted. There is one further point that should be referred to. The depression of the ocean floor and the restoration of the spheroid of rotation means that the diameter of the earth has decreased slightly, and that its period of rotation has altered.

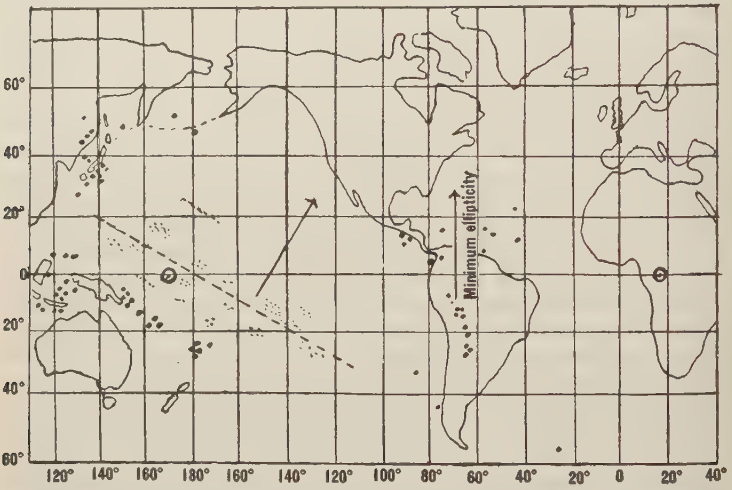


Fig. 1.—Sketch map of Pacific and Atlantic Oceans. ⊙ Equatorial Protuberances ; - - - - Mean trend line of Pacific Islands ; • Deep Foci earthquakes.

The displacement of North America would not be merely a simple fracture of land masses along then existing lines of weakness or where there had been concentration of stress. It should be possible to trace among its many consequences some that throw light on long standing problems. One relates to the dredging of the shallow-water Yoldia fauna from a depth of 2,600 metres in the Norwegian Sea. If this is the absolute position of the sea bottom when that fauna lived, it determines the capacity of the North Pacific Ocean floor depression, for it must accommodate a volume of water to be measured by the area of oceans of the world 2,600 metres deep. This is not too vast to deal with, but if, as will be seen later, it is probably less it will be useful to be able to reconcile the two findings. That the fauna lived and died on the sea bottom where it was found, as Brögger, Nansen, and other Scandinavian authorities believe, must be accepted as a fact. The suggestion that it was dropped there by floating ice seems trivial. A reconciliation, if one is required, may be found in assuming that when the fauna lived the sea bottom was under shallow water and that, as a result of the disturbance caused by the displacement of North America, the sea floor was lowered to its present position.

The most interesting consequence of North America's Quaternary break-away is that affecting the British shelf, which is now divided from the southern end of Scandinavia by the Norwegian depression or " deep ". It does not conform to the usual relation of " deeps " to nearby land masses. Its form is unusual, for its northern end is open and widest. In any replacement of the land masses bordering the North Atlantic, if the 200 metre line is used as approximate boundaries, it will be necessary to close up this " deep " or give reasons for leaving it open. When displacement occurred it can be seen that the northern part of the British shelf and the southern end of Scandinavia would tend to be drawn outwards and apart. This would give the " deep " its present shape, and on this reading it would be a rift. The British shelf must then have rotated with some point near the south-east of England as centre. This would be of little interest but for its bearing on the neglected problem of the origin of the Straits of Dover. Wright (12) has summarized the difficulties very well. The increasing cold temperate elements in the fauna of the newer Pliocene deposits, though the flora indicates a climate like the present, is best explained by a land connection between South-East England and the Continent but, as Wright points out, the opening of the Straits was an event of considerable magnitude for which only a part of Quaternary time can be allowed. A comparatively small rotatory movement of the British plateau, centred on the extreme south-east of England, would inevitably weaken and fracture the land barrier. The Yoldia Sea would complete the operation and, as its erosive power would vary inversely as the width of the openings, the work would be done rapidly. The exceptional elevation of the pre-glacial beach along the west side of the British Isles is evidence that differential vertical movement followed the rupture of the shelf.

The Caribbean Sea furnishes the most striking examples of the consequences of the displacement of North America. Here we are in the rear of the part of the land mass that moved most rapidly. It is here, if anywhere, we can expect to find the equivalent, in a disturbed ocean floor, of the turbulence visible behind any floating mass towed through water. The so-called aberrant Island of Barbados is a good example. It is covered by 100 metres of unmistakable oceanic deposits. The series begins with shallow water beds followed by the oceanic globigerina and radiolarian oozes, and finally by red clay. These are overlain by shallow water foraminiferal ooze and then by coral rock. Schuchert (13) considers that " the great submergence, if such it is, took place essentially in Miocene time, and that in the Pliocene Barbados rose again into shallow water ". He quotes T. C. Chamberlain, who offers an " alternative assumption that the benthos life and correlated conditions were carried up to unusual levels by upwelling currents about the island after it reached the stage of moderate submersion ". It seems permissible to suggest as another, and more probable, alternative that a portion of the old ocean floor was brought to the surface as a result of the disturbance caused by the movement of North America. This assumption would be still more acceptable if some complementary negative movement of the sea floor was known. The voyages of V. Meinesz (14) have furnished gravity determination of far reaching importance. In the east of the Malay Archipelago he found great anomalies in good harmony with the prevailing opinion that movement of the crust has taken place in recent times. He also found that the soundings revealed a more irregular bottom topography for both the Atlantic and Pacific oceans than was known from the charts. All the " deeps " visited were crossed at right angles to the trough direction in order to get the profiles of gravity which make the impression that all of them are uncompensated for or at least for the greater part uncompensated. For the Nares Deep, north of Porto-Rico, he found a great defect of gravity over the middle of the deep. Thus at one end of the lesser antilles we have Barbados with its upraised oceanic deposits and just north of the other end the Nares Deep with its great defect of gravity.

CHANGES OF OCEAN LEVEL.

It has been pointed out above that, though the dominant and controlling ocean movement was the temporary lowering of ocean level of 1,000 metres or more, there were smaller movements, including that due to the abstraction of water to form ice sheets during the re-advance of the ice in late Quaternary times, which were superimposed on the greater and dominant movements. Daly has drawn attention in several publications to the importance of these, and has done much work to evaluate them. It does not underrate the value of Daly's contribution to our knowledge to point out that they need to be discussed in relation to the primary changes of ocean level.

The first part of this change in level was a world-wide lowering, the effect of which would be to rejuvenate all rivers flowing into the oceans and cause the deepening of their channels. If it was certain that all this deepening took place in Quaternary time, data would be available to determine the amount of the fall of ocean level, and Brögger's 2,600 metres would thus receive substantial support. There are, however, other considerations to be discussed later that introduce an element of uncertainty. The most striking effect of the negative movement of ocean level

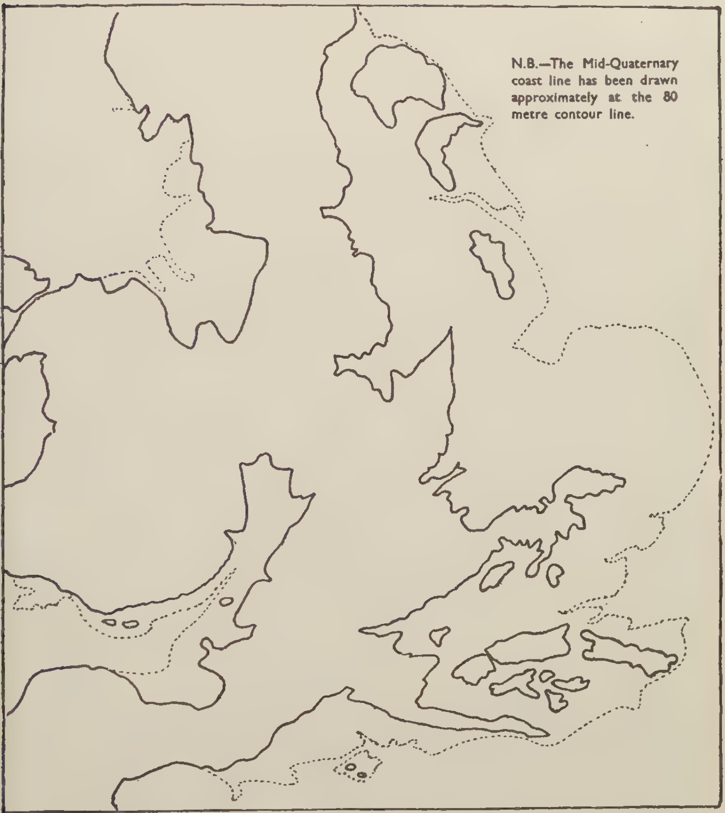

N.B.—The Mid-Quaternary coast line has been drawn approximately at the 80 metre contour line.

Fig. 2.—Sketch map of Southern Britain during Yoldia Sea submergence.

is that it left the land everywhere standing 1,000 metres or more above the then prevailing sea-level. This at once explains the world-wide climatic changes which characterized the Quaternary period. It explains the glaciation of lands in high latitudes wherever supplies of moisture were available and the lowering of the snow line on high mountains within the tropics. It was this, no doubt, that gave rise to the prevalent idea that the world, as a whole, had undergone refrigeration. That the higher stand of the present land surfaces would cause a lowering of temperature must be admitted, but large areas now submerged would then be above water with a new coast line. The new land bordering that coast line would not have undergone refrigeration.

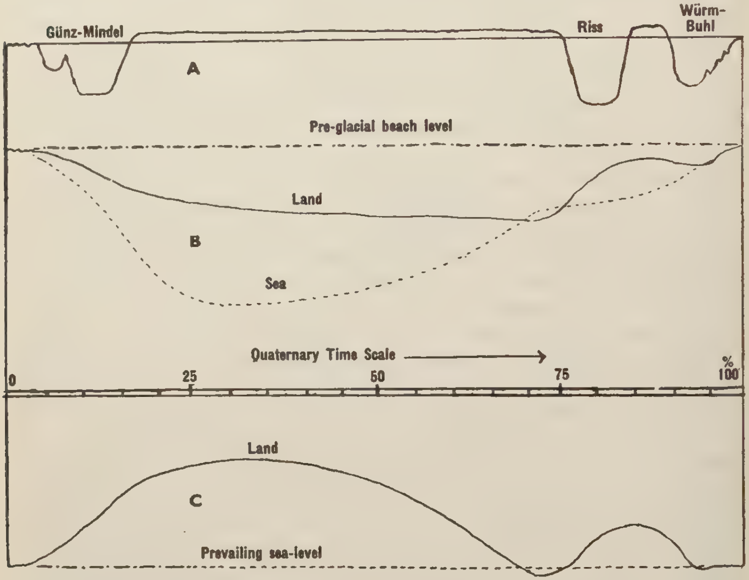
Striking though the effects of the fall in ocean level were, the subsequent rise was perhaps even more important because the isostatically depressed present coast lands were inundated by the rising sea and left deposits that afford most valuable material for correlative purposes. It will be useful to consider this submergence in rather more detail so as to secure a clearer view of its cause and consequences. The facts are definite enough in most cases, but to attribute a marine deposit, now upraised, to a eustatic movement of the ocean is not to explain its origin; it only serves to obscure the real nature of the movements involved. The sea-level was rising and, as the rise was world-wide in extent and even in rate, it was strictly eustatic. But land and sea were involved, and it is the relation of their movements that demands explanation. The Yoldia sea submergence was really the result of the particular rate at which the ocean was rising in the course of its return to the absolute pre-glacial strand level. Had that rate been slow enough the ice sheets would have melted away before the sea reached the pre-glacial level, for the land would have had time to respond to the relief of its load and kept rising. Under those circumstances the sea would only have reached the pre-glacial strand level at the end of the Quaternary cycle, and there would have been no submergence to record. Had the rise of ocean level been more rapid a much more extensive submergence would have occurred and the glacial record would have read differently. The submergence, as recorded in the raised beaches and marine deposits, is a measure of the lag of the land, isostatically depressed by its ice load, in recovering when that load is being removed by the rising ocean. Some further considerations can now be discussed. The rate of ocean rise will be accelerated as the ice melts or is floated off. The land in the course of recovery is more spasmodic in its movement. The early lag is followed by a rapid rise and consequent emergence, but this in turn is slowed down when it reaches the height above the prevailing sea-level, which causes a re-growth of the ice sheets. There will then be a second, but smaller, isostatic depression of the land; the rise of the sea will slow down as water is lost to be locked up in the re-advancing ice sheets, and its rise might even halt for a time until the sea and land approached closer when, accretion of the land ice having ceased, the sea could resume its rise and eventually cause a second, but smaller, submergence. This somewhat detailed discussion will have served one of its objects if it shows the great advantage that is gained by depicting these changes of level of sea and land in absolute terms and plotting them against time as is done in the revised raised beach curve, Fig. 3b. The complete cycle of events can then be viewed as a whole and studied in detail.

When discussing above the use of the term refrigeration, as applied to the Quaternary world-wide climate changes, attention was drawn to the importance of the new coast line that appeared as a result of the lowering of ocean level and to the lands, now deeply submerged, which then bordered it. The present land surface of the globe records the climatic changes that it underwent. The equally interesting chapters of the Quaternary record which deal with the great migrations of flora and fauna now lie deep beneath the sea. In high latitudes the land bordering the mid-Quaternary coast line enjoyed a warm climate, while the uplands behind them were heavily glaciated. The oceans, instead of being chilled by world-wide refrigeration, were probably slightly warmer than now. Along that old and now inaccessible coast line, and up from it, came early Palaeolithic man and the warm fauna when the sea started its upward swing. Along it there must have streamed the migrations that brought the American and Lusitanian elements that were to help re-populate North-West Europe after its glaciation. If 1,500 metres be taken as a measure of the lowering of ocean level—there would be some justification for using the 2,000 metres level if more convenient—this mid-Quaternary coast can be traced on any good bathy-orographical maps when its significance as an explanation of migration problems will be apparent.

APPLICATION OF CRITERIA.

It is now possible to discuss, in the light of later findings, the raised beach diagram, Fig. 1c. of the preliminary communication. There the sea curve, in the absence of knowledge as to the cause of the movement, was made symmetrical. It must now be made asymmetric, for any subsidence of ocean floor must be more rapid in action than its restoration to its former level by the inflow of deep-seated material. The next point to consider is the most probable value for the lowering of ocean level. Had it been the full 2,600 metres of Brögger, the effect should be visible in a proportionate lowering of the snow line on high mountains within the tropics. A lowering of the snow is recorded generally, but the amount, assuming that the usual rate of lowering of temperature by elevation held good, does not suggest an elevation above the then prevailing sea-level of much more than 1,500 metres.

This value will therefore be used in the revised diagram. Another point is the relation of the Quaternary plant bed found at Hötting, near Innsbrück, to the Riss glaciation. They lie under, and appear to have been disturbed by, the Wurm glaciers. The decision carries with it other plant-bearing deposits on the northern side of the Alps, such as Dürnten and Wetzikon, with their " Schieferkohlen ". The flora indicates a temperate oceanic climate a little warmer than that which prevails now. The associated mammalian remains indicate, definitely, the temperate interglacial fauna with *E. antiquus* and *R. merckii.* Now the raised beach diagram shows but one temperate period,



Scandinavia	**Major Glaciation (Arctic)**		**Yoldia Sea**	**Glacial re-advance**		**Littorina Sea**
British Isles	**Major Glaciation (Arctic)**		100'-140' Thames Terrace 100' raised Beach	**Glacial re-advance**		**25' Neolithic Beach**
Alps	**Günz-Mindel**	**Older Loess (steppe climate)**	**Temperate oceanic climate**	**Riss**	**Newer Loess steppe climate**	**Würm-Buhl**
N. Africa	**Arid**	**1st Pluvial Period**	**Arid**	**2nd Pluvial Period**		**Arid**

Fig. 3.—A, Penck's Alpine Climatic Curve (emended ; B, British Quaternary Raised Beach Curve ; C, Derived Land-elevation Curve (derived from B).

that of the Yoldia sea submergence. The Hötting, Dürnten, and Wetzikon plant beds must therefore be of that age. The opinion formerly held was that they were deposited in the Riss-Wurm interval, but the present trend of opinion on the Continent leans to a Mindel-Riss interglacial age for them. The revised diagram will conform to the present trend of opinion. It would appear that the two possible relations in the Alps are :—

(A)	*or*	(B)
Würm Glaciation.		
Newer loess period.		Würm Glaciation.
Riss Glaciation.		Newer loess period.
Plant Beds of Hötting, Dürnten and Wetzikon ; temperate oceanic climate.		
Older loess period.		Riss Glaciation.
		Older loess period.

The balance of probability leans heavily towards (A) ; that is to give the "Hötting Breccia" a pre-Riss age.

The use of the term "major glaciation" to cover the long period in North-West Europe before the interruption caused by the Yoldia sea submergence, with its temperate oceanic climate, calls for a definition in view of the attempts that have been made to recognize Penck's Alpine sequence in the northern drift deposits. It was a period of intense glaciation during which the ice sheets achieved their maximum extension. It was a time when ice flows often from different centres, and using various routes, converged and osculated, now invading and then deserting a particular area, oscillating at their margins as the centres of glaciation shifted, but all of the episodes the result of one long glacial period. The drift deposits left by this major glaciation period are deeply weathered, much eroded, possess a mature drainage system, but lack the usual features of glacial topography. The glacial re-advance which followed the Yoldia sea submergence did not extend so far, and its deposits are fresh looking and retain all the features of glacial topography. It is the interpretation once widely accepted.

The Alpine sequence will now be discussed with the hope of reconciling it with that of the northern glaciated region which has just been described and found to be so definite in character. Now Penck's work in the Alps demonstrated that there were two distinct occurrences of the Arctic fauna and that the temperate fauna separates them. But Penck also found that the loess fauna is always arcto-alpine in character, and never suggests temperate or interglacial conditions. Now the two faunas, arcto-alpine and the temperate interglacial, are well known, and the type of climate that favours the deposition of loess is also well known ; it is definitely a steppe climate. The loess was deposited during both the Mindel-Riss and the Riss-Würm intervals. It is therefore clearly "interglacial" as regards age in Penck's sequence for the Alps, yet it is distinguished by an arcto-alpine fauna. The temperate or truly interglacial fauna is found once only, and that is between the two loess periods. To state the relationship in terms of climate we have here two periods of pronounced steppe climate separated by an interval with a temperate oceanic climate. The results can now be tabulated for both North-West Europe and the Alps.

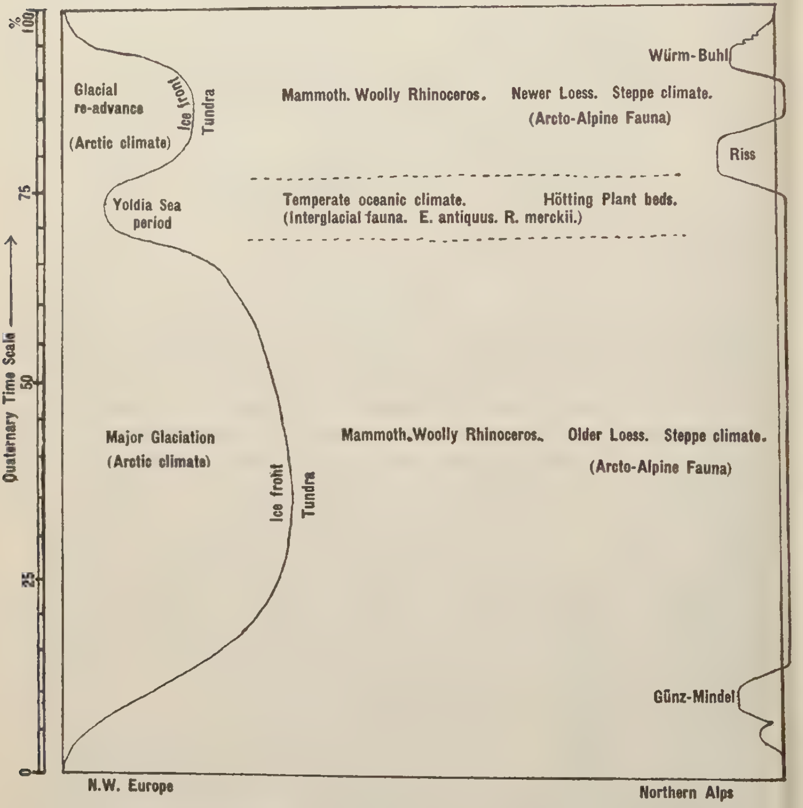


Fig. 4.—Climatic relations of N.W. Europe and the Northern Alps during the Quaternary period.

North-West Europe.	*Alps.*
Glacial re-advance.	Newer loess (arcto-alpine fauna and steppe climate).
Yoldia sea submergence.	Interval (with warm interglacial flora and fauna with temperate oceanic climate).
Major glaciation.	Older loess (arcto-alpine fauna and steppe climate).

The reconciliation has been effected, but only by ignoring, for a moment, the Alpine glaciations and concentrating on the climatic and faunal data. It has also made it clear that "interglacial" carries with it no significance regarding climate, fauna, or flora when applied to the Alpine sequence. There was a Mindel-Riss *interval* and a Riss-Würm *interval* of time between distinct glaciations. The Alpine glaciations now fall into place, all three, the Günz-Mindel, the Riss, and the Würm-Buhl.

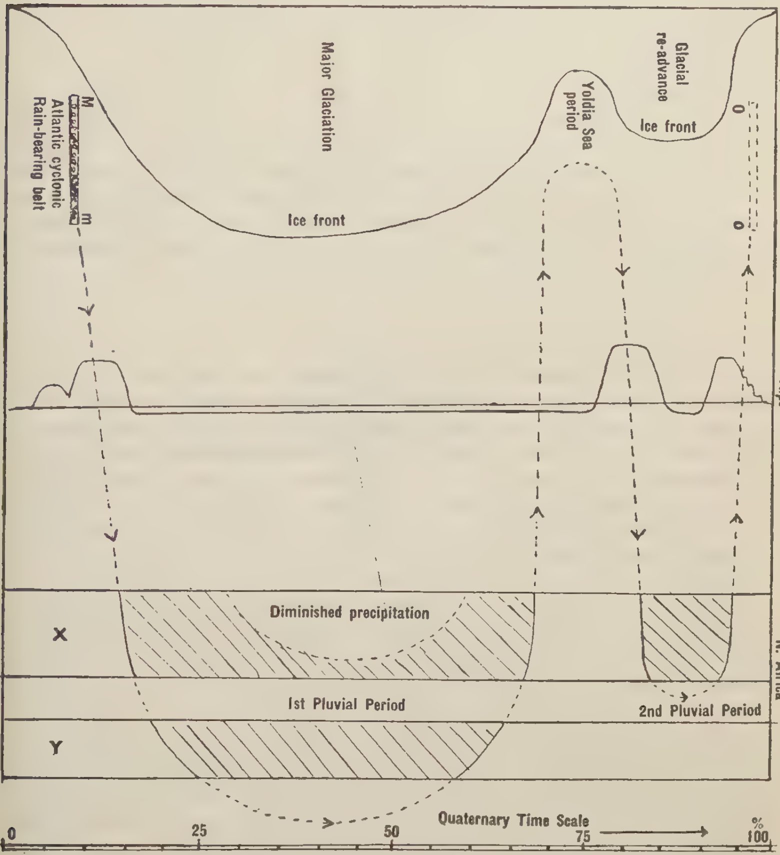


FIG. 5.—The migrations of the Atlantic cyclonic storm belt under the influence of the anticyclone generated by the Northern ice sheet are indicated by arrow points. The outer boundary of the N. Africa pluvial periods is traced by the leading edge of the storm belt. The area of diminished precipitation that interrupted the first pluvial period is traced by the trailing edge. X and Y indicate regions where two or one pluvial periods occur.

occurred when the land stood rather higher above the prevailing sea-level than now, but not greatly so, and was affected by the displacement of the Atlantic cyclonic rain-bearing winds. The amount of precipitation during the advance of the glaciers need not have been greater than to-day, but was greater than that of the two loess periods. The increased elevation above the then prevailing sea-level would reduce ablation by lowering the temperature.

The most important of the correlations are to be found in Fig. 5, where the influence of the northern anticyclone is seen in the past Pluvial periods of North Africa. The ice front curve was derived from the raised beach diagram, Fig. 3b, through the land elevation curve, Fig. 3c. A working model could be made, in which the advances and retreats of the northern ice sheet, during Quaternary time, would mark the boundaries, in space and time, of the Pluvial periods.

CONCLUSIONS.

The main conclusions of the investigation can now be summarized and, together with the correlations that have emerged, shown in diagrams that enable them to be viewed as a whole and yet studied in detail. Every effort has been made to trace the consequences of the conclusions as reached and test them by an appeal to ascertained facts. The extent of the field that would have to be covered eventually was not realized when the first attempt was made to elucidate the real nature of the British Quaternary strand-line movements. The first finding was that the Quaternary period was defined by a temporary lowering of ocean level of 1,000 metres or more. This was based on the failure of alternative hypotheses to work except by making assumptions that assumed the very thing that was being sought for. This temporary lowering of ocean level became the first postulate adopted. Its application to the highly controversial problem of the origin of the coral reefs in the Pacific Ocean seemed to invest it with a high degree of probability. The only sufficient cause of a temporary lowering of ocean level of the magnitude stated was found in a subsidence of the ocean floor which, on the only evidence available, was located in the North Pacific Ocean, but included, in part at least, the present site of North America. The ocean floor subsidence supplied a want in the form of a gravitational pull to rotate North America from its pre-Quaternary proximity to North-West Europe to its present position while the inflow of deep seated material restored the ocean floor to its present level. This suggested distortion of the lithosphere seems, in the light of present knowledge, the best available, and to a generation that has accepted sunken continents and foundered land bridges without obvious signs of repugnance should not be deemed altogether unacceptable. There remains the possibility that the distortion took the form of an approximate tetrahedral deformation, but though this possibility was kept in mind during the investigation nothing appeared to support the idea. It must be remembered, however, that the Tertiary era was time of important horizontal movements of the lithosphere with mountain building on a vast scale as the result. It is possible, and even probable, that the Quaternary distortion was but the final collapse of the over-stressed crust of the earth which the Tertiary earth movements had insufficiently relieved.

The lowering of the ocean level had far-reaching consequences which must be discussed apart from its cause. Its principal consequence was the appearance of a new series of world strand lines 1,500 metres lower that at the beginning of Quaternary time. It caused a vertical displacement of climatic zones which left the present land surface lowered in temperature but exposed large areas of coast land to enjoy an oceanic climate that depended on latitude. That new land surface harboured the fauna and flora displaced by lower temperature from the high ground, and provided migration routes. But this simple vertical displacement of climate was complicated in higher latitudes, where the land was glaciated, by the submergence of the isostatically depressed regions, to the estimated extent of 100 metres or less in the South-East of England, about 200 metres in Scotland and 300 metres in the Baltic. This submergence during the rise of the sea was due to the lag of the land. A more complex diagram was, therefore, necessary to show the movements in higher glaciated latitude. There was a further consequence of these glaciations. The anticyclone generated by the vast ice sheets caused a horizontal displacement of climatic zones by deflecting the Atlantic rain-bearing winds. These movements, too, are shown in the diagrams, which should explain themselves.

The correlations, though substantially those of the first communication, are now more precise in character. They do serve to bring out clearly the significance of Penck's Alpine sequence and its relation to the glacial deposits of North-West Europe. It is now evident why the efforts to recognize Penck's separate glaciations in the northern deposits lacked success. The Alps, instead of revealing a standard series of episodes of world-wide application, were the scene of a special and possibly unique development. Instead of being the standard they must be linked up with the simpler northern sequence as positive and negative, as was suggested in the first communication, when discussing glaciations and interglacials. But they can also, and perhaps more usefully, be regarded as complementary records where the two loess periods of the one are equated with two glacial periods of the other and with the temperate oceanic climate interval connecting them to facilitate precise registration. The anthropologist should find his task easier now that the relation of the Alpine and northern sequences are clearer, but he will still labour under the difficulty that many of his records lie submerged deeply on what were the mid-Quaternary coast lands.

It would appear that the Quaternary climate changes can be explained rationally without assuming any world-wide refrigeration of the globe. This does away with the necessity to invoke astronomical causes. The Quaternary was a period when the normal progress of geological processes was interrupted violently. The cause must be sought for not in cosmic influences, but in the interior of the earth. When discovered, it should indicate also the origin of the forces that at long intervals crumpled up the earth's surface along lines that approximate to part of a great circle of the earth and formed the great mountain ranges. It must also explain why there was such a long interval of time between the Quaternary and Permo-Carboniferous periods, when the earth suffered another violent interruption of the normal operation of geological processes.

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The following papers, with their numerous references, can be read as representing the prevailing views on the subjects discussed in this communication.

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—— "Insular Arcs, Foredeeps and Geosynclinal Seas of the Asiatic Coast": *Bull. Geol. Soc. Amer.*, xliii, 1932, 353–382.

SCHUCHERT, C. "Gondwana Land Bridges": *Bull. Geol. Soc. Amer.*, xliii, 1932, 875–916.

WILLIS, BAILEY. "Isthmian Links": *Bull. Geol. Soc. Amer.*, xliii, 1932, 917–52.

LEVERETT, F. "Comparison of N. American and European Drift Deposits": *Zeit. für Gletscherkunde*, 1909–10, pp. 241–295 and 321–342.

GIRMSUNSKY, A. M. "Gliederung der Quartärzeit": *Zeit. für Gletscherkunde*, 1931, pp. 28–48.

On an Ultrabasic Epidiorite from St. Catherine's, Loch Fyne.

By John D. H. Wiseman, M.A., Ph.D., Department of Mineralogy and Petrology, Cambridge.

THE epidiorite with which this note is concerned is exposed in a small overgrown quarry 50 yards north of St. Catherine's old Chapel, Loch Fyne. The rock is soft and is easy to cut, and it is said that some was used in the building of Inveraray Castle.

In thin section, a striking characteristic is the absence of felspar, epidote, and sphene and the presence of penninite. Its mineralogical composition is thus very distinct from the normal low-grade epidiorites which invariably contain albite, epidote, sphene, and a prochlorite. The colourless to pale green hornblende ($\beta = 1{\cdot}618$) is generally of an acicular variety, and in spite of its low refractive index is probably not a pure tremolite, but a hornblende with high silica and magnesia, and low alumina and alkalies. The well-developed chlorite is intimately associated with the hornblende and has a pleochroism Z yellowish gold, X = Y green. It is optically positive, and has a very low double refraction (anomalous brown or violet interference colours), and $\beta = 1{\cdot}589$. The low double refraction combined with the low refractive index indicates that this chlorite cannot be identified as a prochlorite.[1] According to Winchell's [2] four component diagram it would be classified as an optically positive penninite, i.e. an aluminous chlorite rich in magnesia with reference to iron. A very small amount of a second chlorite is intergrown both with the penninite and the hornblende; this chlorite contains numerous minute inclusions, is optically negative, has X, Y light yellowish gold and Z muddy. Iron ore (mostly magnetite) is well represented in irregularly shaped grains. The only other constituents in this section are two tiny laths of a colourless mineral—probably talc—giving high interference colours.

From the aluminous nature of the dominant chlorite there is an *a priori* reason for inferring that the original rock prior to the regional metamorphism of the area contained a moderate proportion of plagioclase felspar, which has been used up in the production of chlorite and hornblende from the original olivine and pyroxenes. In connection with this hypothesis, the analysis of the St. Catherine's penninite-hornblende-rock is instructive (p. 426).

The analysis (column 1) indicates the ultrabasic nature of the St. Catherine's rock [3]; the high magnesia, the relative abundance of alumina, and the low alkalies being notable features. Chemically it corresponds with a chlorite-actinolite-amphibolite from Schuyler,

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[1] Orcel, J., *Bull. Soc. Franc. Min.*, vol. 1, p. 343.

[2] Winchell, A. N., *Am. Journ. Sci.*, 1926, p. 288.

[3] The presence of ultrabasic epidiorites at St. Catherine's has been previously recorded by the authors of the Cowal Memoir, *Mem. Geol. Surv.*, 1897, p. 64.

Virginia.[1] In order to obtain some indication of the original composition of the St. Catherine's rock prior to metamorphism, the analysis has been recalculated, without water, to one hundred, the result being given in column 3. As compared with igneous rocks it may be classed with the alkaline-poor picrites or the felspathic peridotites. A peridotite dyke from Skye, quoted in column 4, has a similar composition,[2] but the silica is lower; hence the Skye peridotite would contain more olivine than the original St. Catherine's rock.

	(1)	(2)	(3)	(4)
SiO_2	42·63	43·24	45·80	40·90
Al_2O_3	8·23	7·97	8·84	7·56
Fe_2O_3	3·59	1·68	3·85	3·01
FeO	7·08	8·22	7·61	7·31
MgO	25·81	24·72	27·73	29·63
CaO	4·25	5·15	4·56	5·40
Na_2O	0·45	0·17	0·48	0·98
K_2O	0·08	0·02	0·09	0·37
$H_2O +$	6·37	6·97	—	2·98
$H_2O -$	0·23	0·04	—	0·13
TiO_2	0·85	0·52	0·91	1·70
P_2O_5	n.d.	0·14	—	0·10
MnO	0·13	0·16	0·13	0·34
CO_2	—	1·44	—	—
Cr_2O_3	n.d.	n.d.	—	0·11
	99·70	100·44	100·00	100·52

Norm of (3)

Il.	1·67		
Mt.	5·57		
Ol.	Mg_2SiO_4	26·6	30·39
	Fe_2SiO_4	4·03	
Hy.	$MgSiO_3$	31·15	35·90
	$FeSiO_3$	4·75	
Di.	$CaSiO_3$	0·35	0·65
	$MgSiO_3$	0·30	
Or.	0·56		
Ab.	3·67		$Ab_{14}An_{86}$
An.	21·68		

(1) Penninite-hornblende-rock, 50 yards N. of St. Catherine's Chapel, Loch Fyne; Anal. J. D. H. Wiseman.

(2) Actinolite-amphibolite, partially chloritized; Schuyler, Virginia; Anal. R. B. Ellestad.

(3) St. Catherine's Rock recalculated, without water, to 100.

(4) Peridotite dyke, Coir'a'Ghreadaidh, Skye; Anal. M. G. Keyes.

In the norm of 3 there is about 25 per cent. plagioclase of composition $Ab_{14}An_{86}$, which would appear to have been used up in the production of chlorite and hornblende. But the original rock may have contained a little augite, for there is 0·65 per cent. of diopside in the norm and, in addition, when the femic metasilicate proportions are plotted in the triangular diagram of Asklund[3] they fall close to the area characterized by two pyroxenes. It is, therefore, possible that if the calcium aluminium silicate was not present entirely as the anorthite molecule, but was partially contained in an aluminous pyroxene, the amount of modal plagioclase would be slightly reduced.[4] Even if this is the case, a considerable amount of plagioclase must have been used up in the production of chlorite and hornblende from the original olivine and pyroxenes; the alkalies liberated during this reaction would go into the hornblende.

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[1] Hess, H. H., *Am. Journ. Sci.*, xxvi, 1933, 382.

[2] Bowen, N. L., "Evol. of Igneous Rocks," 1928, p. 154.

[3] Asklund, B., *Sver. Geol. Unders.*, No. 17, 1923, p. 77.

[4] Asklund (op. cit., p. 77) has shown that in a norite the amounts of modal and normative plagioclase are approximately equal.

In the more normal epidiorites which correspond chemically to the dolerites or gabbros, the present author[1] has previously suggested that in the low grades a considerable proportion of the anorthite molecule has been used up in the production of hornblende and chlorite from the original pyroxene. During the production of chlorite, silica and lime would be liberated and a reaction between these and the original ilmenite would produce sphene. In the St. Catherine's epidiorite, however, all the lime of the original plagioclase has been required for the production of hornblende from the olivine and pyroxenes, for epidote, sphene and calcite are absent. It is, therefore, possible to explain the occurrence of penninite and the absence of epidote and sphene in this epidiorite by its basic nature.

REVIEWS.

Les Ressources Minérales de la France d'outre-Mer. I. Le Charbon: II. Le Fer, etc. pp. 245 + 436, with many figures. Paris: Société d'Éditions Géographiques, Maritimes et Coloniales, 1933 and 1934.

In this Magazine for December, 1933, there appeared a notice of a work on the general geology and mineral resources of French territories beyond the seas. The two volumes now to hand form a continuation of the same, of a more detailed kind, under a slightly different title. The first is confined to coal and deals mainly with French Indo-China, the only important coal-bearing area under the French flag.

The second volume is of much wider scope and more general interest, since it comprises accounts of deposits of iron, manganese, chromium, nickel, tin, tungsten, graphite, beryllium, molybdenum, cobalt, titanium, and vanadium, in the order named above. It is not quite clear why graphite is thus sandwiched in among the metals.

The treatment adopted is very comprehensive, and in some cases, for example tin and tungsten, amounts to a very complete general account of the world's resources of those metals. The description of the mineral wealth of New Caledonia and Madagascar will be extremely valuable to economic geologists in all parts of the world, since it brings up to date the information hitherto contained in many writings, especially those in the well-known works of Monsieur Lacroix, who appears to be the presiding genius of this admirable series.

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[1] Wiseman, J. D. H., *Proc. Geol. Soc. London*, 1934, p. 22. The complete memoir on the Highland Epidiorites has yet to be published.

Die Bodenschätze des Staates Minas Geraes (Brasilien). By Dr. B. von Freyberg, Erlangen. pp. 453, with xii plates and 73 text-figures. Stuttgart: Schweizerbart'sche Verlagsbuchhandlung (Erwin Nägele), 1934. Price M 54.

THE appearance of this book will be heartily welcomed by all geologists, and especially by those interested in the economic side of their subject. As is well known the State of Minas Geraes is one of the most highly-mineralized regions of the world : it has yielded great quantities especially of gold and such names as Ouro Preto, St. John del Rey, Morro Velho, and Passagem are household words in the literature of mining geology. Furthermore, the State also contains apparently almost inexhaustible resources of the highest grade iron and manganese ores, besides diamonds, platinum, and many other minerals. It has also the distinction of possessing the deepest mine in the world, Morro Velho, which in March, 1933, had attained a depth of 2,410 metres, or just over 7,900 feet vertical.

As the author points out in his preface, the literature is much scattered, often very inaccessible, and includes a multitude of errors ; hence an account mainly based on personal acquaintance with the country cannot fail to be of the greatest value.

The general plan of the geology is fairly simple, the oldest formation lying in the east and the newer successively to the west, ranging from probably Archaean, through Algonkian, to an equivalent of the Gondwana System. The most important economically, the Minas System, which includes the iron and manganese ores, appears to be late pre-Cambrian, like so many iron-bearing formations in other ancient continental blocks. Space will not allow here of a detailed account of the author's most interesting descriptions of the great gold-bearing primary and secondary deposits of the region ; it can only be briefly noted that the great sulphide-carbonate-quartz ore-body of Morro Velho is one of the finest known examples of an ore-shoot, and so far shows little or no sign of falling off in value, even at its present great depth.

The problem presented by the origin of the vast deposits of iron ore of the itabirite type is of extraordinary interest. The ores are clearly metamorphic rocks of a high grade ; haematite-schists and quartz-haematite-schists grading into quartz-schists. Some varieties contain an extraordinarily high proportion of iron, even up to 70 per cent, when a little magnetite is present, and a large bulk are practically pure haematite. The phosphorus and sulphur are very low. It seems best to call the hard solid types itabirite and the soft sandy varieties jacutinga, this last being sometimes gold-bearing. The name *canga* is used for fragmental more or less weathered surface material. There can be little doubt that some day this will be the greatest ironfield of the world, when technical difficulties as to fuel and transport are overcome.

The origin of manganese ores presents a subject of very great geochemical and mineralogical interest. Most of the large occurrences can doubtless be explained by the ordinary rules of mineral chemistry and thermal metamorphism, substituting manganese for magnesium in the fundamental equations of the dedolomitization series; the genesis from these primary masses of the workable material is due to oxidation and hydration, being unusually complicated, however, by the large number of possible manganese oxides. Dr. von Freyberg does not tackle this in detail, although he evidently attributes the ores to processes of this type. The Brazilian occurrences appear to have close analogies with the gondites of India. The strong tendency of manganese to form garnet is evidently an important factor.

Of outstanding interest among the numerous economic minerals of Minas Geraes is the diamond: in past times some very large and famous stones have been found, and the history of the industry as here summarized is of much interest. It seems probable that the primary home of the diamond here, as in Africa, will ultimately prove to be in association with ultrabasic rocks of the kimberlite type.

Finally, it may be useful to geologists in general to give in a very condensed form the geological subdivisions recognized in Minas Geraes, as set forth in this book, omitting the unimportant Tertiary and all the superficial deposits. A British geologist would in most cases write *system* where Dr. von Freyberg uses the word *series*.

	Bauru Series Uberaba Series	Cretaceous.
	Gondwana Series	Trias.
*		
	Bambuhy Series	? Devonian.
	Geraes and Indayá beds	? Silurian.
	Itacolumy Series	Cambrian. Algonkian.
*		
	Minas Series	? Algonkian.
	Crystalline Gneisses and Schists	? Huronian. ? Archaean.

The lines indicate unconformities, and important episodes of folding occur at the horizons marked with an asterisk. This table is copied from page 20 of the book, but a smaller table on page 14 is not quite consistent with it, as there the Itacolumy Series is shown as forming the uppermost division of the Minas Series.

R. H. R.

THE MICROSCOPIC DETERMINATION OF THE NONOPAQUE MINERALS. Second Edition. By E. S. LARSEN and H. BERMAN. pp. 266, with 1 plate and 7 text-figures. *Bull. U.S. Geol. Survey*, 1934, No. 848. Price 20 cents.

IN the preparation of a new edition of this indispensable work on determinative mineralogy a number of changes have been introduced which will further enhance its usefulness. The long chapter on new data, all the information in which was incorporated also in the tables, is wisely omitted. It has thus been possible to expand these tables by more than 500 new entries, the whole now representing about 1,200 mineral species, and yet to effect a slight reduction in the total number of pages. It is interesting to notice that the number of species for which the optical character is still unknown amounts to only 2·4 per cent. A new feature which will certainly be approved by all who use this now standard work is the addition of separate tables in which are assembled the data of important groups such as the pyroxenes, amphiboles, and zeolites.

F. C. P.

OUTLINES OF PHYSICAL GEOLOGY. By C. R. LONGWELL, A. KNOPF, and R. F. FLINT. pp. 356, with 297 figures. New York: John Wiley and Sons; London: Chapman and Hall, 1934. Price 18*s*. 6*d*. net.

THIS is a shorter version of the *Physical Geology* by the same authors, published in 1932. The text has been much abridged, but the number of illustrations has been reduced only from 341 to 297. Some knowledge of common rocks and minerals is assumed from the beginning, but there are chapters on sedimentary and igneous rocks in the middle of the book, and an appendix on minerals at the end.

The special features of the book are conciseness and clearness of statement and fullness of illustration. There is no waste of words, and there is no obscurity. At times the desire of the authors to get as much as possible into the space has led to a little baldness, but the illustrations prevent any loss of interest. They are exceptionally good and well chosen. Many of them are photographs, but perhaps the most useful of all are the very instructive and well-drawn block-diagrams. Most of the subjects are, naturally, American; and, for that reason, most of them will be new and interesting to the English student.

P. L.

CORRESPONDENCE.

THE OLIGOCENE IN NORTHERN SYRIA.

Sir,—In a recent paper on Oligocene fossils from Palestine it was suggested by one of us (pp. 340, 348 of this volume) that the type-horizon of the species *Chlamys quinquepartita* (Blanckenhorn) (*Zeitschr. deutsch. geol. Ges.*, xlii, 1890, 352, pl. xix, figs. 2, 3), originally described from near Aintab, in northern Syria, would prove to be Oligocene and not Eocene, as believed by its author. With the kind consent of Professor Blanckenhorn we have now examined one of the syntypes of the species, a natural mould of the exterior of the shell from which the " squeeze " illustrated in pl. xix, fig. 3, of Professor Blanckenhorn's paper was prepared. The matrix proves to contain several specimens of *Lepidocyclina* ranging up to at least 11 mm. in diameter. This proves conclusively that it is of later date than Eocene and fully justifies the interpretation of *C. quinquepartita* as an Oligocene species. We thank Drs. L. Picard and K. Winter, of the Hebrew University, Jerusalem (where Professor Blanckenhorn's types are deposited), for the privilege of seeing this type-specimen.

It should be noted that the specimen of this species figured in Pl. xviii, Fig. 2, of last month's paper is a left valve and not a right one as stated.

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London, S.W. 7.

PETROLOGY AND THE WESTERN RIFT OF CENTRAL AFRICA.

Sir,—I have read with interest Dr. E. O. Teale's letter in the June issue of the Geological Magazine. I am sure no petrologist would have the temerity to suggest that such reactions as the conversion of hypersthene to garnet in the charnockites, dolerite dykes to garnet-amphibolites, and the production of wide-spread brecciation and mylonization of very resistant gneisses, all took place under a shallow cover such as the Mid-Pleistocene to Recent times would probably have provided in the region under discussion. Dr. Teale is under a misapprehension when he believes me to hold such an opinion. Reference to my second paragraph on p. 505 and again on p. 508, makes it clear : (1) that I recognize the necessity for the " removal of a considerable amount of overburden " before such rocks could be exposed at the surface; (2) that I subscribe to the views of Wayland and Hirst that the tectonic activity which gave rise to the Lake Albert Depression in Tertiary and Quaternary times must have commenced at an earlier period.

The association of the fine-grained mylonite of Pl. xxxviii, Fig. 1, with the rifting is as clear as that observed by Bailey Willis in the scarp at Kibero (see p. 504). The introduction of some alkaline liquid giving rise to the sodic amphibole, etc., establishes a connection with the Rift Valley movements, though this connection may well be in the nature of an end-point rather that date the movements as a whole.

On p. 504 I referred to the shearing and mylonization along the Nandi Escarpment, which Wayland believes to be a very old fracture—older than the peneplanation—which was in part rejuvenated by the rift-forming forces. He states that " we have primary rift-faults formed during an early stage of continental uplift, subsequent and secondary faults due to gravitational collapse along escarpments and also in consequence of volcanic extrusions, and at any rate one pre-peneplain rejuvenated fault." It seems highly probable that, in the case of Lake Albert, formation of the primary rift-fault zones commenced a very considerable time before the culmination of the movements. Indeed, the instance of the Nandi Escarpment strongly suggests that the primary fault zones may have been commenced in one period to be rejuvenated during a later one, in which case their age may well be considerable and Pre-Karroo.

Lastly, although I believe that the Uganda zone of the Western Rift, containing as it does such a mighty upthrust mass as Ruwenzori, can only be explained by a compressional theory, I do not hold that the other East African rifts have necessarily been formed in the same way. I see no reason why tensional theories should not be applied to some cases while one at least is attributed to compression.

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